# PRACTICAL POINTS

(FOR STATIONARY, LOCOMOTIVE AND MARINE)

ENGINEERS FIREMEN, ELECTRICIANS

MOTORMEN AND MACHINISTS.

(ILLUSTRATED)

REVISED AND ENLARGED EDITION

BY

JOHN S. FARNUM, M.E.

THIRTIETH THOUSAND.

PUBLISHED BY

MECHANICS' SUPPLY COMPANY.

CHICAGO, ILL.

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# PUBLISHERS' NOTICE.



During the past few years the question of licensing engineers has been agitated in every part of the United States and Canada. A number of states have already enacted such legislation as to compel all kinds of engineers to procure a State License, others have provided for municipalities to pass ordinances bearing on the subject, while still others are to-day seriously considering the matter. The result is bound to be, that in a short time, for the protection of life and property, no man will be allowed to run an engine without first going before a Competent Board and passing an examination whereupon a license will be issued to the applicant.

This work is designed NOT TO MAKE AN ENGINEER OF A MAN but to aid the proper persons to pass the required examination, whether it be for City, State or Government license.



MECHANICS' SUPPLY CO.

# INDEX.



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# ILLUSTRATIONS.

# PREFACE.

This edition has been thoroughly revised and enlarged so that now I believe it to be the most complete work of its size for stationary, locomotive or marine engineers, firemen, etc.

This work goes into the points deeper and explains them with the plainest of simple language, so that men of limited education can understand as well as a man of high education.

We all know that the proper way for a man to learn is by practice. But the two, practice and theory together will make a man more perfect. Reading of other mechanics' ideas will enable a man to better his own ideas and perform his work more perfectly.

Those preparing for an examination and expecting to receive a license should by all means procure this book as its practical suggestions throughout, will enable them to get their license.

The book treats on boilers, engines, firing, combustion, indicators, dynamos, motors, electricity and has valuable receipts and rules.

Trusting that my efforts in trying to please the general run of engineers will be appreciated by all. I am

Respectfully yours,

JOHN S. FARNUM.

*The following questions and answers are for locomotive, stationery and marine engineers and firemen to use as a guide in preparing themselves for an examination. First you must fill out a blank and have same properly signed before going before the examining board. Then await your turn and be ready when called.*

## CONSTRUCTION OF BOILERS.

Q. What is a steam boiler?

A. A steam boiler is an air tight vessel and may be divided into three divisions or six classes, namely: locomotive, marine, tubular, flue, hanging fire box and upright boilers. The hanging fire box is fired inside of itself, tubular and flue boilers are fired externally having an attached furnace.

Q. How are marine boilers fired?

A. They are fired inside of themselves.

Q. Are boilers single or double riveted?

A. They are both. Single for low pressure and double for high pressure.

Q. Name the different strains the boiler has to contend with?

A. Bursting strain and tearing.

Q. Is the strain greater on the sides than on the ends?

A. Yes.

Q. Why so?

A. Because the steam pressure has a larger surface to work on.

Q. How are boilers strengthened?

A. They are strengthened by stay bolts and braces.

Q. Name the different braces in general use?

A. The stay bolts, the angle brace, crow-foot, side brace, longitudinal and dome brace. In hanging fire box boilers the crown sheet is braced by what is known as crown bars.

Q. Of what construction is a successful and economical boiler?

A. The chief points are in proper circulation facilities and good construction. For tubular boilers place the tubes in vertical rows leaving out centre row. The circulation in a boiler is up on the sides, down the centre. Ziz-zag tubes check the circulation and give poor results.

Q. State the strain on a stay bolt and how is the calculation made?

A. The stay bolts, as a rule, support an area of thirty-six square inches, multiply the area by the steam pressure and you will have the strain upon each stay bolt. The distance that stay bolts should be set apart should not exceed six thousand pounds per square

inch cross sectional area. To determine the distance multiply the cross sectional area of bolt by 6,000, divide by steam pressure and extract square root of quotient.

Q. State the surface of plate a stay bolt has to support?

A. The support is represented by the rectangle or area enclosed between four bolts.

Q. How is the rectangle known between four bolts, each six inches apart?

A. It is known by multiplying one distance by the other; 6x6=36 square inches, each bolt has to support.

Q. Of what use is a hollow stay bolt?

A. It is used to supply air above the fire and help combustion.

Q. Compute the horse-power of a horizontal tubular boiler, 5 foot diameter, 16 foot long, containing 78 3 inch tubes, each tube 16 foot long?

A. Multiply diameter of shell by 3.1416 to get circumference 15.70 feet, the lower half of shell being the only heating surface divide this by 2 which equals 7.85, multiplied by the length of shell 16 feet equals 125.60 square feet. The circumference of 3 inch tube is, 9.42 inches by the

same rule multiplied by its length, 192 inches equals 1808.64; which multiplied by the number of tubes, 78, equals 141,073.92 square inches, or 979 square feet, which added to the square feet of the shell equals 1107 square feet, divided by 15 equals 73⅔ horse-power.

Q. Name the number of square feet of heating surface allowed to a horse-power in different makes of boilers?

A. Horizontal tubular boilers 15 square feet, vertical 12 square feet, locomotive 12 square feet, flue 10 square feet and plain cylinder 9 square feet.

Q. How many square feet of grate surface does it take to consume 12 pounds of coal?

A. One square foot.

Q. How many pounds of water will be evaporated by one pound of good coal?

A. The average will be 6 to 10 pounds of water. The average result is about 25 to 50 per cent. below this, for it is estimated by some of the best authorities that 1-16 inch of scale in the boiler causes a waste of 10 to 15 per cent. of fuel and in this proportion upwards according to the thickness of scale.

Q. How would you know the amount of

water a boiler is evaporating by a given number of lbs. of coal used in one hour, say 1,000 lbs.?

A. Simply divide 1,000 (or lbs of coal) by 7½, and answer will be cubic feet of water. Multiply ans. by 7½, and the result will be the number of gallons evaporated in one hour.

Q. How many gallons of water in one cubic foot, also how many cubic inches?

A. There are 7½ gallons in a cubic foot, and 1728 cubic inches in a cubic foot.

Q. Name some of the causes of boiler explosions?

A. Explosions of steam boilers are generally due to defective material, defects of construction, improper management and natural causes. An explosion takes place when the resistance is less at some point than the pressure to which it is subjected, and may happen even when the pressure is very low. The explosion of a boiler is not an instantaneous action, although it seems so. It is a well defined and rapidly succeeding series of operations. The rupture commences at a point where the resistance offered by the material is less than the strain to which it is subjected and it extends into

the adjoining part when these parts are too weak to sustain this increased strain that the rupture already made brings to bear on them. together with the shock due to the motion that the edges of the fracture make while seeking a new state of equilibrium. In case of an explosion the steam pressure does not fall the instant the rupture takes place ; on the contrary the pressure continues very nearly up to the time when all the water has escaped from the boiler. An explosion is so much more terrible as there are more fractures made prior to the moment when the boiler is entirely emptied of its water.

Q. Is it dangerous to let water run low in the boiler?

A. Yes, it is very dangerous as the plates become red hot, and the softened plates will tear open and may produce an explosion if the hot part is hot enough or if the adjoining parts do not offer sufficient resistance.

Q. Is the steam pressure lowered when feeding a boiler with low water?

A. When water is fed into a boiler when the water is too low it almost invariably lowers the pressure of the steam.

Q. Is it dangerous to force water into a low water boiler with a hot fire in the furnace?

A. Yes it is always dangerous to feed, before dampening the fire because the water injected quiets the ebullition and increases the surface exposed to the heat.

Q. Is it dangerous to empty a boiler when the tubes or flues are still hot?

A. Yes, it is dangerous; for such actions cause fractures of the transverse riveting in such manner as may not always be shown by leakage, and this effect may very easily produce an explosion when next the fires are lighted or in a short time afterwards.

Q. Why should a tubular boiler be kept clean on the outside?

A. Because when a plate is covered with soot or incrustation most of the defects cannot be seen, therefore it is very important that boilers should be kept as clean as possible externally as well as internally.

Q. Name the various steps in an explosion which have heretofore been mentioned?

A. First, a fracture in a plate followed by a rending; second, a violent bursting out of water and steam; third, a falling pressure; fourth, portions of the water are propelled with great violence against the shells of the boiler and shattering it by the expansive force of the steam disseminating throughout

the body of the water; fifth, the steam generated from the liberated water imparts a high velocity to the fragments, converting them into projectiles, thus spreading ruin and destruction around.

Q. From the various experiments and investigations what conclusions have been arrived at?

A. A violent explosion may take place in a boiler when there is plenty of water in it; second, that a moderate pressure of steam may produce a terrific explosion when there is plenty of water; third, that a boiler may explode under steam at a less pressure than it has stood without apparent injury from a water pressure or hydraulic inspection, therefore hammer test is the better; fourth, a rupture will be followed by relief of pressure with or without explosions as the fracture is extended or otherwise; fifth, that an explosion rarely occurs in an externally fired boiler from low water.

Q. How is the safe working pressure of a boiler found?

A. Multiply twice the thickness of the shell by the tensile strength, and divide the answer by five times the diameter of the shell in inches.

Q. State the proper place for a lower gauge cock in a tubular or flue boiler?

A. Two inches above the upper row of flues.

Q. State the proper place for a lower gauge cock in an upright boiler?

A. One-third the distance between the two flue sheets, measuring from the top flue sheet.

Q. What is known as the fire line of a boiler (Tubular)?

A. The fire line is between the water line and the top row of flues.

Q. What is known as the water line?

A. The water line is known as two inches above the flues.

Q. What is corrosion?

A. Corrosion is one of the strongest destructive forces to which the boiler is subjected. Internal corrosion is caused by the concentrated acids of the water, which attack the most susceptible portions of the plates or tubes, and if the acids are volatile or the liquid acids carried by foaming or priming into the steam space, the plates there also suffer. Corrosion is very capricious in its action, some boilers are attacked on the shell, others will suffer principally in the

tubes, and others at the rivets and seams. The erratic action must be ascribed to the gravity of the acids at work, their concentration in certain parts due to the circulation of the water, to the nature of the iron or steel, and to other causes more obscure. Uniform corrosion is that species of the wasting of plates, tubes, etc., in a more or less even manner, and is like ordinary rusting in its character. Pitting or honey-combing is another form, well marked by the sharply defined edges they present, and is usually found in patches of various sizes.

Q. What causes grooving or channeling?

A. Grooving or channeling, as it is usually termed, is due to the mechanical action produced by unequaled expansion and contraction.

Q. Where would be a good place to force in the feed water to overcome grooving?

A. Introduce the feed water near the water level in the boiler instead of near the bottom, it will help some.

Q. Would you consider it dangerous to empty a boiler when the tubes or flues are hot?

A. Yes.

Q. Is it dangerous to fire up a boiler too rapidly?

A. Yes, it is very dangerous, as where the draft and combustion are sufficient for a white heat, the plates, no matter how good they are, cannot resist with certainty.

Q. Name over several kinds of explosions?

A. Scaly boilers, by overheating, defective circulation, corrosion, explosion of gas in the furnace of flues, hydraulic testing by straining, letting water run low and overheating, then pumping cold water into the boiler.

Q. What causes defective circulation?

A. When boiler tubes are too close together and not having room enough for the water to circulate when making steam.

Q. How far apart should the tubes or flues be for proper circulation?

A. They should be ½ the diameter of the flue itself apart, and in perpendicular rows.

Q. How is the tonage strain on the crown sheet of a fire-box known?

A. Multiply the length by breadth in inches, divide by 12 for feet; multiply ans. by steam pressure and divide by 2,000. Ans. is tons.

Q. State rule to find amount of strain a crown sheet will withstand?

A. Simply use same rule as above and divide the tonage by 2.66 if a 5/8 inch plate, 4 if a 1/4 inch plate, and 2 if 1/2 inch plate (thickness).

## MANAGEMENT OF BOILERS.

It is fully as important to manage a boiler properly as it is to have it properly designed and constructed. From the time the boiler is set at work it is subject to destroying forces which must he counteracted as much as possible. Therefore the person under whose immediate charge the boiler properly comes, should be a strictly sober and competent man.

**Q.** What is the first duty of a fireman or engineer before starting a fire under a boiler ?

**A.** He should see that there is plenty of water in the boiler by trying the guage cocks.

**Q.** What next should he look after ?

**A.** He should see that the blow-off cock is shut, that the hand-hole and the man-hole plates do not leak, or if they do he must tighten them with wrench and hammer; also look at seams and tube or flue ends for leaks.

**Q.** If circumstances will allow how should a boiler be cleaned ?

**A.** When the fire is hauled, the throttle valve on the steam pipe next to the boiler should be shut; the ashes and cinders quenched and wheeled to the ash pile; the furnace and ash pit doors and the dampers should be closed, and the steam

blown off at the safety valve until there is only about five pounds pressure; then the safety valve should be lowered to its seat.

Q. Would you blow out the boiler then?

A. No, let the water remain in the boiler until it and the furnace is cool, then let the water and slush run out through the blow-off cock.

Q. Why not blow out water with a light pressure on?

A. It has a tendency to weaken the seams and also the boiler in general, by uneven expansion.

Q. What is next done after boiler is empty?

A. When the boiler is empty, the man-holes and hand-holes may be opened, and the boiler rinsed out; then examine carefully inside; the scales must be knocked off with light blows of a pick or scraped with bars and chisels, or loosened with angular wire chains, etc., then wash the boiler clean with water.

Q. When should the scale be removed?

A. The scale should be removed as soon as possible after the water has been let out of the boiler, before it has time to dry and harden, if any repairs are to be made to the braces, etc., they should be made and the boiler closed up.

Q. How about the outside and connections of boiler?

A. The flues and connections should be swept

and the boiler bottom scraped with a wire brush. After above the boiler is ready for filling with water, which should be done at once, and then it should be examined carefully for leaks, which if found should be repaired at once, before the boiler is put into use again, if, however, it is not intended to use the boiler for some time it will be well to drain all the water out of it, and to dry it thoroughly by pans of charcoal, and then set a pan or two of lime into the boiler, and close it tightly.

Q. Why dry the boiler and set in it pans of lime and close it tight?

A. To prevent oxidation.

Q. Name the principle tools about a fire room or boiler room?

A. A full set of tools consist of a shovel, slicebar, T bar pricker, hoe, coal hammer and devils claw, together with a broom and dust brush, and also a chipping hammer, a flat cape and diamond point chissel, and wrenches to fit the nuts and bolts about the boiler, a monkey-wrench and screw driver.

Q. State the tensile strength of a boiler tube, say three or four inches in diameter, or how is the strength of the tube calculated longitudinally?

A. The standard thickness of a three inch

tube is .109 of an inch; its circumference is 9.4248 inches. There would have to be pulled apart 9.4248 x.109=1 0273 square inches of iron to separate the tube lengthwise. One square inch will hold from 40,000 to 50,000 pounds. Assuming 45,000 pounds as the tensile stength per square inch of section, it would require 45,000 x 1.0273=46,288 pounds to pull the tube apart longitudinally.

Q. What pressure will a tube resist when expanded into the headsheet of a boiler beaded, and not beaded?

A. The Hartford Steam Boiler Inspection and Insurance Co. prepared and had tested three inch tubes expanded into plates with a Dugeon expander, without beading. The first was expanded into a 3-8 inch plate, and it required 6,500 pounds to pull it out. The two others were expanded into 15-32 inch plates, and it required 5,000 and 7,500 pounds respectively to pull them out. They later prepared two similar specimens, both tubes left projecting beyond the tube sheet and flared and expanded into 3-8 inch plates. The observed stress which first produced yielding was 20,500 pounds in one and 19,000 pounds in the other, 500 pounds additional being required in both cases to completely dislodge the tubes.

Q. When calculating the load on a safety valve, is any allowance made for atmospheric pressure on the back of it; if not, why?

A. No, because the gauge pressure in which the results are figured and expressed signify the difference between boiler pressure and atmospheric pressure, not the absolute pressure in the boiler. There must be atmospheric pressure in the boiler when the pointer stands at zero, and one pound above the atmosphere, or 15.7 absolute, when the gauge indicates one pound.

Q. How much hydraulic test should a boiler be put to, to carry 100 pounds pressure of steam?

A. It is usual to subject a boiler to hydraulic pressure 50 per cent. greater than the steam which it is to carry. For 100 pounds pressure of steam, the hydraulic test should be 150 pounds.

Q. Is the hydraulic test for boiler the better way to test a boiler?

A. No, the hammer test is the best.

Q. Why is the hammer test the better of the two?

A. Because boilers can be strained by the hydraulic test and show no leak when the pressure is used, but when steam is raised the boiler expands and opens the strain caused by the cold water test

Q. Can you give a good short rule and example to figure a safety valve, and know at what pressure it will blow off?

A. Yes, after having taken all the measurements, length of lever fulcrum, weight of lever valve and stem, and weight of ball, we divide the fulcrum into the length of the lever, multiply by weight of ball, add the weight of lever valve and stem when connected at the fulcrum, and divide by the area of the valve. Example: lever twenty-four inches long, fulcrum four inches, weight of lever, valve and stem, 32 pounds; diameter of valve $2\frac{1}{4}$ inches $=$ 3.9 area. Weight of ball 40 pounds, $4 \div 24 = 6 \times 40 = 240 + 32 = 272 \div 3.9 = 70$ pounds steam pressure boiler will blow off.

Q. Are spring pop valves figured?

A. No, they are set with a guage, specially made for the purpose.

Q. Of what use are safety pop valves?

A. They are supposed to release the boiler of all pressure above a point at which they are set.

Q. State the proper size of a safety pop?

A. As a rule three square feet of grate surface equals one square inch of pop valve (area).

## BOILER INCRUSTATION AND CORROSION.

The prevention of incrustation and corrosion is of vital importance. In fact, there is no subject of so much importance in the promotion of the efficiency, economy and life of the steam boiler.

Among the evil effects arising from the presence of incrustation and corrosion can be directly attributed, a loss of fuel, varying from 1 to 37 per cent.

If waste of fuel were the only evil incident to the mismanagement of steam boilers, it might be tolerated in localities where fuel is abundant and cheap;.but other great evils result from incrustation, such as burning of iron, granulation of the material, bagging, blistering, and fracture of the sheets, flues and tubes. Also pitting of iron, and many other forms of corrosion. All of which having the tendency of destroying the tensile strength, elasticity, and resistance of the iron, and rendering it liable to explosion at any time with disastrous effect.

If the steam boiler is expected to render proper service,to be safe and durable, and an easy steam generator, certain conditions must be complied with. It must be intelligently managed, care-

fully fired, not over taxed, and above all, kept safe and clean on the inside.

To properly protect the interior of the steam boiler, to keep the iron clean and in good safe condition, chemistry is undoubtedly the only source from which to seek relief and protection from the disastrous results occasioned from the above named destructive agents. The corrosive and destructive acids contained in solution in water, can only be neutralized by the intervention of a chemical basis, and it must be borne in mind than no mechanical means can fulfill this requirement.

In consequence of the demand for an efficient and reliable preventative of incrustation and corrosion, a great variety of nostrums have been placed upon our market, and offered to steam users under attractive names, and for which exceptional merit is claimed; but an analysis of these preparations, together with a knowledge of their components, and resulting actions, dissipates these claims and conclusively demonstrates that, with few exceptions, the manufacturers of the same have not the requisite knowledge of chemistry, that would entitle their preparations to the confidence of the steam user.

The author has had a wide experience in the capacity of Boiler Inspector for many years, in

which experience he has come in contact with nearly all the steam users in several states, and during this experience, I may honestly affirm that I have found but one preparation which I consider entirely reliable as a remedy for incrustation and corrosion in steam boilers.

This article has gained a world-wide reputation, and is endorsed by the leading authorities not only thoughout the United States, but also in foreign countries, to which it is exported in large quantities. The article I refer to is manufactured in Philadelphia, Pa., by Mr. Geo. W. Lord, a practical manufacturing chemist and engineer, who is also well known as an author and contributor to some of our best scientific works on steam engineering.

His preparations are known as "Lord's Boiler Compound," but I will here state that the words "Lord's Boiler Compound" are only his trade mark, under which such different compounds are prepared, as each individual steam user may require; or such specific preparations as may be required, where the same or similar waters are used in certain territories, and Mr. Lord's extensive trade is no doubt, due to his scientific knowledge and skill in furnishing a preparation, which is suited to the requirements of each individual case.

You may have noticed circulars and other advertisements of boiler cleansing preparations, which the manufacturers claim to be purely vegetable. It is a well known fact that vegetable matter principally consists of acids, carbon, earthy salts, etc., and the active and soluble properties contained in these preparations, are acids which are more harmful to the boiler than any boiler incrustation.

Oil is also frequently employed as a preventative of boiler incrustation, but any intelligent engineer will understand that this invariably induces overheating, and burning of the plates, tubes and flues.

Oil has the property of penetrating the pores of boiler incrustation, and detaching it in large fragments from the boiler surfaces, thereby precipitating this aggregate mass directly over the heating surface, causing burning, blistering, and bagging of the material.

This is a dangerous practice, and one liable at all times to invite boiler explosions.

Oil is also a convenient cloak, under which to introduce vegetable and mineral acids into the boiler, and this daring practice is of frequent occurence, and is worthy of criminal prosecution.

## PROPER FIRING.

Firing is only done properly when the fuel is consumed in the best possible way, that is, when no more is burned than is necessary to produce the amount of steam required and to keep the pressure uniform. To reach this end complete combustion must be attained in the furnace, and to know when this is going on, is when the fuel is burning with a bright flame evenly all over the grate furnace.

Q. How do the colors show when the fire is badly managed?

A. Blue flames, dark spots and smoke, are the best evidence of incomplete combustion.

Q. What is the cause of bad combustion?

A. It is caused by not having air enough above the fuel in the furnace. Experience is the best teacher although points from a book are very applicable in all cases of firing different makes of boilers.

Q. How should the tools be placed about a boiler room?

A. Every tool should have its place and be kept there when not in use, and if broken should be repaired at once. Never keep furnace doors open longer than absolutely necessary, and the firing should be done as quickly as possible.

Q. Why should the furnace door be closed quickly and the firing done quickly?

A. To prevent contraction of the boiler bottom from the cool air entering the furnace.

Q. Should a fire be stirred often?

A. No; the fire should not be stirred any more than is necessary.

Q. Why?

A. In order to avoid the waste from small coal from dropping through the bars.

Q. Suppose the chimney draft was very strong, how could it be controlled?

A. Simply close the damper partially, also the ash pit doors.

Q. Name the proper thickness of fires under boilers?

A. For anthracite coal the thickness should be from six to eight inches generally. For bituminous coal from eight to ten inches, and with coke from ten to twelve inches.

Q. How large should the coal be when thrown into the furnace?

A. Not larger than a man's fist.

Q. State the best way to start a fire under a cold boiler?

A. Cover the grate bars with coal for about two-thirds of their length from the bridgewall, and should pile a little wood, cob-house fashion,

on the open bars, and put a few lighted shavings or oily waste in the mouth of the furnace, partly close the furnace doors, and wholly close the ash pit doors.

Q. Why is coal thrown back on the grate bars first?

A. The coal on the grate bars prevents air from coming through them and impairing the draft, while the partial opening of the furnace door supplies air to the burning wood and directs the flame over the coal in the back end of the furnace, gradually heating the coal up to the point of ignition.

Q. What is next done?

A. After the wood is burning well, coal may be thrown upon it and the furnace doors closed the ash pit doors being then open.

Q. When is more coal thrown in on the fire?

A. As soon as the fire will bear it being done, and the fire is gradually pushed back until there is a full fire on the whole length of the grate bars.

Q. Should a fire be hurried?

A. No, it must be allowed to "come up" as it is termed, very gradually, and to do this put on a little coal at a time.

Q. How should a fire be kept?

A. The fires should always be kept level and

of a uniform thickness, with the exception that at the sides, corners, and at the bridge wall it must be enough thicker to prevent cold air from leaking through.

Q. When should a fire be cleaned?

A. The fire should be cleaned when the clinkers and dirt accumulate to an extent sufficient to clog the draught.

Q. How are the fires cleaned?

A. Boilers with wide furnaces it is better, perhaps, to clean only one half at a time and let the fire burn up well on that side before attempting to clean the other half.

Q. Where there are several furnaces all leading into the same chimney, how should they be fired?

A. They should be fired alternately in order to keep the steam at a regular pressure and observe the greatest economy and fuel.

Q. Is it a good idea to wet coal just before firing?

A. No, it is wasteful of heat and produces corrosion.

Q. Is it safe to close the damper entirely?

A. Never close the damper entirely while there is fire on the grates as gas may collect in the flues and an explosion may take place which

would ruin the boiler; it is also apt to "burn down" the grate bars.

Q. Are there any reasons to believe that boilers have exploded through the explosion of gas?

A. Yes, there are reasons to believe that boiler explosions have been produced in this manner.

Q. Is it proper to bank a fire?

A. Yes, a banked fire properly kept up is conducive to longevity of the boiler, because of the less amount of contraction and expansion induced owing to difference in temperature.

Q. How should the feed-water be supplied?

A. The feed-water should be supplied regularly and continuously and the water-line should be kept at a regular height, and there should never be less than three or four inches in depth over the highest part of the furnace, flues, or connections exposed to the flames or hot gases; but it is very bad practice to carry the water too high in a boiler as it will cause priming.

Q. Which is the proper way to try the safety-valve?

A. By raising steam until the boiler safety-valve begins to "simmer," noting the pressure by the steam gauge at the moment.

Q. Can a safety-valve not be raised by hand?

A. Yes, but that would not inform me that it would blow off at the proper time with proper pressure. Steam pressure should never be allowed to exceed its highest blow-off limit.

Q. Suppose the steam gauge was showing that the steam was rising rapidly what would you do?

A. Simply feed water in the boiler at once, partly close the damper and the ash pit doors. If in spite of this the steam is still rising, open up the furnace doors a little, and feed more strongly.

Q. Suppose the water rose in the glass higher than practicable, what should be done?

A. Open the blow-off a little, at the same time watch the water-line very closely, by continuously trying the gauge cock.

Q. Suppose the water was dangerously low when the steam started to raise would you pump in water?

A. No; if the pump is in motion at the time, leave it continue. The furnace doors must be opened and damp, small coal and ashes thrown over the fire, then in a few minutes the boiler will be cool enough to allow pumping up. In such a case examine the top row of flues for leaks.

Q. How often should the gauge glass be blown through during the day?

A. Several times every day, also the gauge cocks should be tried about every half hour.

Q. Why try the gauge cocks when you know by the glass gauge you have water?

A. To know if the glass is in working order.

Q. What is "foaming"?

A. Foaming is a violent mixing of the water and steam in the boiler which results in "priming" or the carrying of the water, in the state of a fine spray, with the steam into the engine cylinder, often knocking out a cylinder-head, rapidly lowering the water-level in the boiler sometimes so much as to be dangerous.

Q. What generally causes foaming?

A. Foaming is generally caused by irregularity in firing or feeding, impure water, especially if it be greasy; contracted steam space; too small extent of area at the water-line; from the tubes being crowded together; the boiler not being clean; the throttle or safety-valve being opened too suddenly; the boiler not being clean, and in marine boilers changing the feed water from salt to fresh, or the reverse.

Q. Explain how one can know when a boiler is foaming?

A. It is generally shown in the glass gauge

by a sudden rising or falling of the water, or by boiling or showering of the water down through the glass, also by a peculiar sputtering sound given upon opening the gauge cock.

Q. How can it be overcome?

A. It can be overcome by partially closing the throttle and opening the furnace doors and feeding strongly; sometimes, however, it is necessary to blow out a little water from the boiler, but this should not be resorted to except in extreme cases. Keep the boiler clean, and the water clean, and little of such trouble will occur.

Q. How much pressure per square inch of steam should there be in a boiler before the needle on the steam gauge begins to move?

A. About 15 pounds pressure per square inch.

Q. Why?

A. The atmospheric pressure in the boiler must be overcome.

Q. By what power is a steam gauge needle moved; also state the use of the circular bent pipe between boiler and gauge?

A. The needle is moved by expansion of the condensed water left in the crooked pipe

under gauge. If it were a straight pipe and steam came in direct contact with the gauge it would sweat the glass and not show a true state of affairs.

## LOCOMOTIVE FIRING.

Q. What is your understanding of steam pressure as shown by the steam gauge?

A. The steam gauge shows the steam pressure on each square inch on the inside of the boiler.

Q. What is the result on the exhaust steam going through the stack?

A. It carries the air up through the stack with each exhaust and by drawing it from the front end produces a partial vacuum there.

Q. In what way does the exhaust steam create draft on the fire?

A. When the air is drawn out of the front end, the air and products of combustion in firebox flow through the flues to fill the space, this in turn allows the pressure of the atmosphere to force fresh air up through the grates and fire and makes a steady flow of air into the firebox.

Q. What is your idea of the proper size

of stack—inside diameter, length, and taper or straight inside?

A. That is a pretty hard question to ask a young fireman, but I have noticed that when a smaller stack is put on an engine it increases the draft on the fire. If the stack is very short, it seems to work better if it is made smaller in proportion to the size of the cylinder than if it is a long one. I also notice that a good many of the taper stacks have a bushing inside of them that is straight, or the same size at both ends. Some of our engines have stacks two inches smaller than the cylinder, others have stacks three inches smaller. A freight engine in heavy service with a very small stack is very hard on coal, when with light service she might be very economical. Where the stack is small the exhaust nozzle can be made larger and exhaust have the same effect on the fire, this helps to do away with the back pressure in the cylinders.

Q. Will air enough come through the grates and fire to form perfect combustion of the coal?

A. Not under all conditions.

Q. Is it necessary to admit any air above the fire?

A. Generally it is. The gas formed from the coal that does not combine with the air coming through the grates and fire must have another portion of air admitted above the fire to help it burn, or it will pass through the flues and out the stack unconsumed and wasted.

Q. What is the object of the holes in the firebox door?

A. To admit air over the fire; they are also convenient to light up the deck and tender coal space if the holes are so drilled that the light will shine through lining and doors.

Q. Will the cold air mix with the gases from the coal and burn at once, or must it be heated first?

A. It must be heated first, very hot.

Q. What effect would a very small exhaust nozzle have on the fire?

A. It makes a very fierce draft and lifts the coal up on the grates each exhaust; unless the fire is closely watched it will pull holes in it.

Q. When the fire burns most in the front end of the firebox what does it indicate?

A. Too much draft through the bottom rows of flues.

Q. How is this remedied?

A. By changing the position of deflector plate in the front end or the petticoat pipe.

Q. What is the object of the brick arch?

A. To hold the gases that are formed from the coal in the firebox longer, so they will combine with the air and burn, to heat the air to a high temperature so it can do this; to prevent the emissions of dense black smoke; to protect the flues from the air coming in through the open door when firing and it checks the effect of the exhaust on the fire so that small particles of coal that would otherwise go through the flues and out the stack are held in the firebox and burned.

Q. Does it save any coal? How?

A. On most engines it does, on some it does not. With some varieties of coal it does not seem to make much difference. It saves coal because it helps to burn the gases that otherwise would go out unconsumed and wasted. If the side sheets are patched or leak any the arch makes them worse, as it keeps them hot after the other parts of the firebox are cool.

Q. Explain how you would fire an engine

to make her steam well, run light on coal and avoid unnecessary smoke?

A. I would keep an even fire by firing a little at a time and often—break the coal to a proper size so it would burn evenly all over the firebox, as large lumps and fine coal never burn alike or economically—a large chunk of coal takes considerable heat from the fire to get it burning and there is a large portion of it that does not burn for some time after it is put in the box, this takes up heat instead of giving it out—look out for places where the engineer usually shuts off so that the fire will be burned bright, this will avoid a good deal of black smoke.

Q. How do you keep smoke from trailing over train when running shut-off?

A. If there is still fresh coal on the fire that is still giving off black smoke, crack the door a very little and it may be necessary to put on the blower enough to draw some air through the fire and burn the smoke and also raise the smoke above the coaches. This depends upon the good judgment of the fireman; if the blower is on too strong it does more harm than good.

Q. What effect does it have on the fire

to open the firebox door when the engine is working?

A. It lets the air come in the easiest way, through the door instead of through the fire. When firing, if the door is closed each time between putting in scoops of coal, it keeps the fire burning properly, giving it a chance to ignite each scoop of coal as it is put in. If you keep the door open 'till the whole firing of coal is put in, there is not enough heat in the fire to ignite the fresh coal and keep up steam. An open door is hard on the flue sheet.

Q. What effect does wetting the coal have?

A. With soft porous coal the water gets in the cracks in the lumps of coal and it splits open as soon as it gets hot. With very fine coal it helps it to coke into small chunks that stay in the box and burn instead of going out with first exhaust.

Q. What will you do with a fire that is banked?

A. If it is on account of a clinker, get the clinker loose from the grates and out of the firebox if possible. If banked from too heavy firing, fire on the thin places only, use

coarse coal in holes in the fire; fire on the white spots till it is level and proper thickness again.

Q. How does the blower operate?

A. Just the same as the exhaust, only not so powerful.

Q. Will the blower prevent black smoke?

A. Yes sir, but a free steaming engine should not make much black smoke when shut off if handled properly, the blower should be used very light when necessary for this purpose.

Q. If blower is put on too strong when cleaning the fire, what is liable to happen?

A. The flues begin to leak on account of a strong draft of cold air striking them. If the "old man" is around and catches you at it, it means ten days' suspension.

Q. Do you consider it wasteful to have an engine blow off frequently?

A. Yes sir, but if both men on an engine do not work together it is a hard matter to prevent it. With some crews they work into each others way so you know just what to look out for and engine rarely blows off. Then if you can carry up to within a few

pounds of blowing off all the time between stations, it uses less coal and water and is easier on the engine.

## STEAM.

Q. What is steam?

A. We might say that steam is a vapor formed from water, but that is not sufficiently definite, and demands some explanation. The passage of any liquid into the gaseous state is called vaporization, and the term "evaporation" especially refers to the slow production of vapor at the free surface of a liquid and boiling to its rapid production in the mass of the liquid itself.

Q. Explain a vapor.

A. The term "vapor" is confined to evaporation without boiling or ebullition; the term "steam" indicates the gaseous form of water produced by ebullition, which is commonly understood to take place at 212 deg. Fahr., or about it.

Q. Does the temperature of the boiling point of water rise when the pressure is increased?

A. Yes, though not in the same ratio, but

the same amount of pressure always corresponds to the same temperature of the boiling point in the same liquid.

Q. When does a liquid boil?

A. A liquid boils when the tension of its vapor is equal to the pressure it supports.

Q. If it takes a certain amount of heat to raise the temperature of a cubic foot of water from sixty deg. Fahr. to the boiling point at 212 deg. Fahr., and to further raise that water into steam of the same temperature it still requires a further expenditure of coal, what becomes of the extra amount of heat developed by the additional amount of coal?

A. It is not shown by the thermometer; it is absorbed in driving apart the particles of water and keeping them apart in a gaseous state as steam.

Q. State the degrees of heat at different pounds steam pressure, commencing at boiling point of water, then at ten pounds per square inch, etc.

| | | | |
|---|---|---|---|
| 10 lbs., | 240 deg. | 120 lbs., | 350 deg. |
| 20 " | 260 " | 140 " | 360 " |
| 50 " | 298 " | 150 " | 365 " |
| 80 " | 324 " | 160 " | 370 " |
| 100 " | 338 " | 180 " | 380 " |

Q. What heat would you call steam?

A. "Latent heat," while thus employed.

Q. What heat would it require to convert one pound of water into steam at atmospheric pressure?

A. Science shows that it will take the same amount of heat sufficient to melt three pounds of steel or thirteen pounds of gold.

Q. Which is the better water for steam purposes and use in boilers?

A. Rain or atmospheric water which does not contain minerals, and is therefore best adapted for steam purposes.

Q. Is it pure?

A. No; for in its descent to the earth it washes out the solid particles of dust and the germs of animals and plants, and in addition to these it dissolves the oxygen, the nitrogen and carbonic acid, which respectively cause corrosion and slight organic deposit in the steam boiler but it is almost entirely free from elemants necessary to cause incrustation.

Q. After the rain has fallen to the earth and mixed, is it good then?

A. Rain falling upon the earth's surface is absorbed by the porous soil, and the material of which the soil is composed being in a great degree soluble, it is absorbed, and the water becomes contaminated with mineral matter, there-

fore the rain water before mixing with the earth is the better of the two.

## WATER.

Q. Of what is water compose?

A. Water is composed of volume, one part oxygen and two parts hydrogen, or by weight, oxygen 88 9-10 parts, hydrogen 10 1-10 parts. Water is one of the most wonderful substances in nature.

Q. Is water compressible?

A. Yes, slightly, at the rate of 1-100 of an inch in 18 10-100 feet by each 15 pounds per square inch pressure.

Q. Will water restore its elasticity?

A. When the pressure is removed its elasticity restores its original bulk.

Q. Has water a solvent power?

A. Yes, water has a greater solvent power than any other known liquid, and it is due to its absorbent nature that it is rarely found pure or free from foreign substances in solution.

Q. State the different weights of water in different proportions?

A. Water is 8 15-100 times heavier than air. One standard U. S. gallon of fresh water weighs eight and 1-4 pounds and contains 231 cubic inches. A cubic foot of water weighs 62½

pounds, and contains 1728 cubic inches or about $7\frac{1}{2}$ gallons. Water boils at 212 degrees above zero and freezes at 32 above zero.

Q. Will water part with all substances held in solution and become pure; and when?

A. When evaporated into steam or frozen into ice.

Q. Does water expand when freezing?

A. Yes, when water is pure and in small quantities it is transparent, odorless, colorless, tasteless, and is a bad conductor of either heat or electricity.

Q. Give an idea or explanation how water becomes so valuable, and where does it go?

A. The ocean is the great and final receptacle for all water which escapes evaporation. From its surface the water evaporates, rising into the atmosphere to fall again in the form of rain; entering the soil it again issues in the form of springs with a fresh quantity of dissolved mineral matters which it bears on to the ocean. Thus again and again the rain drops have performed the voyage to the sea, each time laden with a little cargo of dissolved salts that had not been intercepted and evaporated. In this way the ocean has become very saline, as it is the receptacle for the saline matters which are washed out of the earth's crust, until the

average impurities of the Atlantic reaches 2139 grains per gallon, while the Dead Sea contains 19,736 grains of saline matter per gallon.

Q. Which is the greatest mechanical power in nature?

A. Simple water.

Q. Why so?

A. By its conversion into steam it drives locomotives, steam ships and industries of every description. It is also the greatest leveler; it moves mountains and fills valleys; it floats the ships from shore to shore and makes commercial intercourse possible with every inhabitable spot on the globe. All our stratified rocks, sandstones, slates and limestones were formed by the action of water.

Q. What else do we owe to water?

A. We owe to water its solvent properties and its chemical action in metalic deposits, such as our iron, copper, zinc, gold and silver ores, and even coal.

Q. What else?

A. To its physical properties, its relation to heat, we owe all the phenomena of clouds, dew, rain, fog, snow and frost. It supports the plants, brings them mineral food from the soils and protects them from excessive heat. Animals depend upon, yet after all it is only the agent

of the sun. It is the sun power that makes plants grow; it is sun power that moves everything in the world, and water is merely the sun's agent. The loss of water would produce the same condition of things on earth that we now notice in the moon.

Q. How much water is there in proportion to the earth?

A. 1-24000 part of the earth. The crytalline rocks at the earth's surface now contain a larger quantity of water than this, and the moment our earth cools enough to absorb four thousands of one per cent of moisture the ocean will disappear.

Q. If we lost our ocean what would happen?

A. We would loose our atmosphere, also the opening or pores in the rocks will receive the atmosphere by gravitation and we shall have the same conditions of things as now exist on the moon. Water is the great source of all our health and well being, and again at other times it brings disease and death. The subject particularly in its relation to health as well as for steam purposes cannot be too carefully studied.

Q. Can you tell the pressure in pounds per square inch of a column of water?

A. Yes, multiply the height in feet by .434 approximately every foot of elevation is equal

to one-half pound pressure per square inch.

Q. For what does this allow?

A. This allows for ordinary friction. The mean pressure of the atmosphere is usually estimated at 14 7-10 pounds per square inch, so that with a perfect vacuum of mercury 29 9-10 inches, or a column of water 33 9-10 feet high.

## INJECTORS AND PUMPS.

Injectors and pumps are known among the engineers as devices for supplying boilers with water, or for delivering liquid to any height by the help of steam.

Q. Are there many kinds of pumps and injectors for feeding boilers?

A. Yes, the old style single action plunger pump, with two valves, double action with four valves, and the duplex, with 8--16—32, etc., valves according to size (see illustrations.) The injectors are in two classes, namely, injectors and inspirators for feeding boilers.

Q. State the reason for having more than eight water valves in duplex pumps.

A. To prevent loss of water when pump is working.

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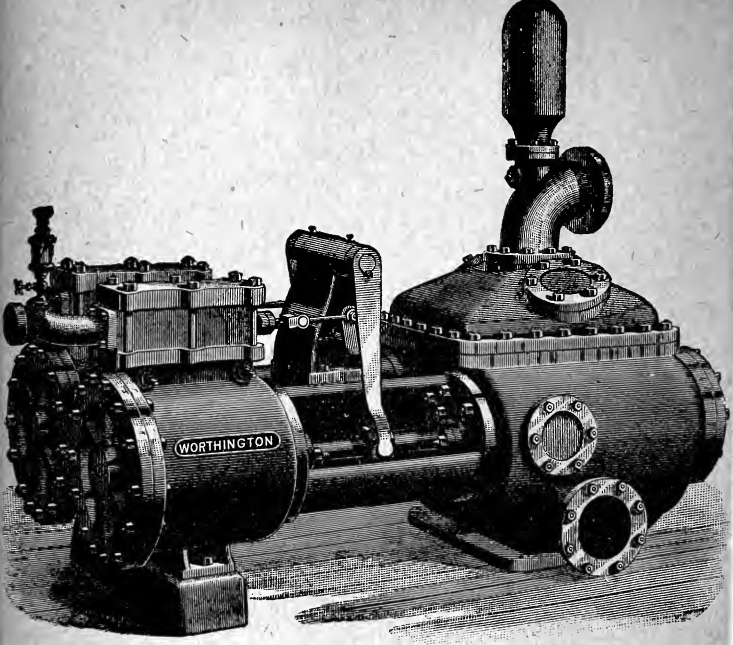



WORTHINGTON DUPLEX PUMP.

**Q.** Can you set the steam valve of a duplex pump?

**A.** Yes; by lifting the valve chest cover, centering or plumb the long and short lever, then adjust both valves equally over the parts and the pump will be O. K.

**Q.** How is it known when a pump is working water?

A. By the stroke of the pump or by the pet cock, steady stream and no air.

Q. In connecting an inspirator or injector to draw water how should the connection be made?

A. On the boiler the connection should be from the highest dry steam point and direct from the boiler, and the water end should be as straight as possiple, one size larger than connection, and be sure suction pipe is air-tight. Do not try to work hot water, as the inspirator or injector will break connection.

Q. How is an injector or inspirator cleaned inside of incrustation?

A. By placing the injector or inspirator in a bath composed of one part muriatic acid and eight parts soft water; leave in bath over night.

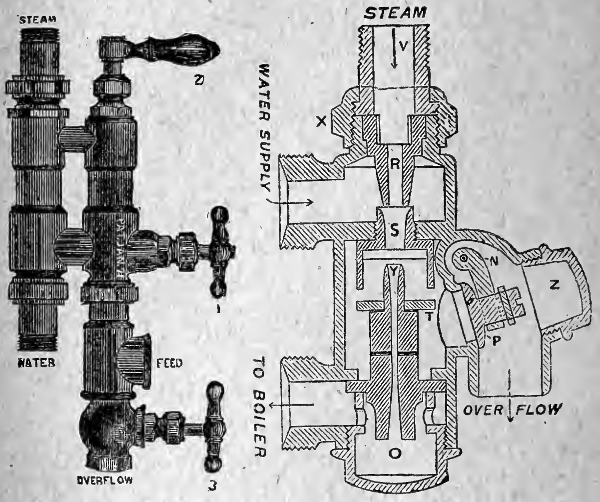
Q. Explain how water is delivered in a boiler through the injector or inspirator.

A. It is explained in this way: The water being drawn to the injector or inspirator by a vacuum it condenses the steam, and the steam condensed forms a light body moving at a high velocity and imparting its momemtum to the heavier body and forcing it along the feed-pipe into the boiler. Never use more steam than there is water to condense it.

Q. How does one know when an injector or inspirator is at work or not?

A. By the singing sound it has upon the ear.

Q. Will an injector or inspirator work hot water




INJECTOR, EXTERNAL AND INTERNAL.

A. It will not.

Q. What is it that keeps the water moving into the boiler?

A. The continual flow of steam and its condensation.

Q. State the velocity of 120 lbs. pressure through an inch pipe?

A. Three thousand feet per second.

Q. Suppose the injector will not work when it has always been reliable before; where would you look for the trouble?

A. Look for it at steam and water supply.

Q. If not there where would you look for it?

A. See if enough water is in tank to supply injector, see if tank valve is open, see that the water is not too warm, not over 150 deg. Fahr., notice if hot water returns after injector is shut off, if not, then next notice if the supply water condenses all the steam, next uncouple tank hose and look for dirt and rubbish in the strainer.

Q. What is the use of the steam nozzle?

A. Its use is for the actuating steam jets to pass.

Q. What is a combining tube?

A. A combining tube is where the steam and water mixing takes place.

Q. Explain the delivery tube?

A. It is where the maximum velocity of the mixture of steam and water is attained; also where the jet overcomes the counter pressure from the boiler.

Q. Into how many classes may injectors be divided?

A. Into two general classes, namely:

Lifting injectors, and non-lifting. These two classes may again be divided into single tube, double tube, self-adjusting, re-starting, open or closed overflow injectors.

Q. How would you operate the "Monitor"?

A. See that water valve is full open, then open steam jet valve; steam will blow through the overflow and lift the water. When water appears at the overflow, then open large steam valve more or less, according to pressure, and until the overflow "runs dry," then close the jet valve.

Q. How is the injector stopped?

A. Close main steam valve.

Q. Is water regulated sometimes at water valve?

A. Yes, when pressure is below 140 pounds; from 140 to 200 pounds the injector will not need any regulation at water valves.

Q. Can the feed-water in tank be heated?

A. Yes, by closing overflow valve and opening steam valve, this prevents steam from escaping through the overflow and forces back into the tank through the suction.

Q. How is the lever-handled "Monitor" injector operated?

A. Pull out the lever a short distance to

lift the water; when water runs from the overflow, steadily draw back the lever until the overflow stops.

Q. Is it a good idea to give more steam after the overflow has stopped?

A. No. It would cause the injector to break.

Q. Will an injector take water from the tank, supposing there was no vent?

A. No, it would break.

Q. What generally causes an injector to break?

A. The main causes are, namely: not enough water supply, straws, sticks, mud, cinders, passing through bad strainers, also corrosion or scale in the casing of the injector, leaky joints and overheated water.

The ordinary speed to run steam pumps is at the rate of 100 feet of piston travel per minute. The nearer pumps are placed to the water, the more easy will be the suction. When a vacuum is formed in a suction pipe the pressure of the external air forces the water up the pipe, provided the lift is not too great. Theoretically water can be lifted by vacuum thirty-three feet, but in practice not more than twenty-three feet. 28½ feet can be realized Water at a high

temperature cannot be raised any considerable height by suction, because vapor forms and prevents the formation of a vacuum. When pumps are used for hot water they must be placed very close to the fluid or be supplied from a head. Pumps cannot lift water heated to a temperature when steam forms in any quantity, and for this reason feed-water is never injected into a boiler at over 212 degrees and generally between 150 and 200. Double action pumps keep up a steady stream and thus economize labor, as every stroke is effective. In single action, common plunger pumps, every other stroke works, which makes the double action by far the most economical.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston speed being the standard speed) divide the number of gallons by 4, extract the square root and the product will be the diametor of pump cylinder. To find the quantity of water elevated in one minute running, at 100 feet of piston speed, square the diametor of the water cylinder in inches and multiply by four. Example: capacity of five inch cylinder is desired. The square of five inches is 25 x 4 = 100 gallons per minute. From this should be deducted about 25 per cent. for actual service.

The area of a steam piston multiplied by the steam pressure in pounds will equal the total pressure exerted. The area of water piston multiplied by pressure of water per square inches will equal the resistance.

## COMBUSTION.

Q. What is combustion?

A. Combustion is an energetic chemical combination of oxygen with some other substance accompanied with light and heat. Tho substance with which it combines is called fuel.

Q. Name the products of perfect combustion?

A. The products are water, steam and carbonic acid, and to assure it a sufficient high temperature and a sufficient supply of oxygen are necessary.

Q. Give the different air spaces between grate bars for different coals.

| | |
|---|---|
| Lehigh Anthracite Pea Coal - | One-quarter inch space. |
| Schuylkill " " " - | Three-eighth inch space. |
| Lehigh Anthracite Chestnut Coal | Three-eighth inch space. |
| " " Stove Coal - | One-half inch space. |
| " " Broken Coal - | Five-eighth inch space. |
| Cumberland bituminous - | Three-quarter inch space. |
| Wood - - | Three-quarter to one inch space. |
| Saw dust - | Three-sixteenth to one-quarter inch space. |

### TEMPERATURES OF FIRES WITH COLOR.

| Appearance | Tem. | Fah. | Appearance | Tem. | Fah. |
|---|---|---|---|---|---|
| Red, just visible | 977 | Deg. | Orange, deep | 2010 | Deg. |
| Red, dull | 1290 | " | Orange, clear | 2190 | " |
| Red, Cherry dull | 1470 | " | White heat | 2370 | " |
| Red, Cherry full | 1650 | " | White bright | 2550 | " |
| Red, clear | 1830 | " | White Dazzling | 2730 | |

The foregoing table will enable the temperatures to be determined by the appearane of the fires. The first step towards affecting the combination of any gas is to ascertain the quantity of air required to supply that amount of oxygen.

Q. State the amount of air required to consume one pound of coal.

A. It will require about 247½ cubic feet, or 18 pounds.

Q. State the amount of air there is in one pound?

A. There is 13½ cubic feet.

Q. What is the comparative weight of nitrogen to oxygen?

Q. It is five to one. Having ascertained the quantity of oxygen required for the saturation and combustion of the two constituents of carburetted hydrogen, the remaining point to be decided is the quantity of air that will be required to supply this quantity of oxygen.

Q. How is this determined?

A. This is easily determined, as we know precisely the proportion which oxygen bears in volume to that of air, for as oxygen is 1-5 the bulk of the air, five volumes of the air will be necessarily required to produce one of oxygen, and as we want two volumes of oxygen for each volume of the gas, it follows, to obtain these

two volumes, we must provide ten volumes of air.

Q. What does smoke indicate?

A. Smoke is a sure evidence of improper combustion. but it does not follow that where there is no smoke combustion is perfect. The perfect combustion of coal in a furnace can only be affected by a sufficient supply of oxygen contained in the air in a proper manner.

Q. What is necessary to kindle or burn any substance?

A. The substance must be heated to a certain degree, and kept up to that temperature in order to burn.

Q. When gas is being expelled from the coal in a furnace where is the greatest heat?

A. The greatest heat is in the gas, as no particle of solid coal (or rather coke) can burn while gas is being expelled a lump of coal may, however, be giving out gas in one place while it has been expelled from another, and remaining coke already ignited.

Q. Does coke produce smoke while burning?

A. No; the duration of smoke, therefore, means the time during which the gas is distilling from the coal. In combustion the heat must be referred to the chemical union of the substances, and the luminosity to the high temperature.

Q. What is it that ignites the phosphorous on a match?

A. Simply friction ignites it at 150 degs., and, in burning, it gives out heat enough to ignite the sulphur of the match at 500 degs., which in turn ignites the wood of the match at 800 degs., and by means of the last flame we ignite the kindlings, and in turn ignite the larger pieces of wood and the heat given out raises the temperature of the coal sufficiently for it to ignite at 1,000 degs.; and thus we see that the ignition of the coal is the last of a series of progressive steps, each increasing in temperature.

Q. Will flame enter a tube of a boiler of ordinary size, if so, how far?

A. A flame never enters a tube more than a few inches from its mouth, no matter how near the tubes are placed to the surface of the fire, the flame is extinguished on entering them.

Q. What is it that burns at the other end of the tube, if flame does not pass through?

A. It is an unignited compound, known as carbonic oxide, which passes through and having a low igniting temperature takes fire after reaching the air at the top of the chimney or end of the flue, making a blue flame attending the conversion of carbonic oxide into carbonic acid.

Q. Was this the flame that was extinguished ering the tube or flue?

**A.** No, all the combustible matter contained in the flame at the moment of extinction is lost, as no benefit is gained by its burning at the creator of the chimney it can only impart that full heat by its complete combustion.

Q. How many units of heat will one pound of coal yield?

A. One pound of coal will yield 13,000 units ten per cent. of which is wasted in radiation forty per cent. escapes up the chimney and fifty per cent. utilized. The combustion of coal is to a great extent a mystery.

Q. How is the philosophy of combustion known?

A. The philosophy is known through chemistry.

Q. What is coal?

A. Coal is a compound substance, and may be decomposed by heat in several distinct elements. In combustion we deal principally with but two, viz: Carbon in the form of coke, and hydrogen, known as gas. These two elements practically contain the full heating properties of the coal.

Q. Does coal commence to burn immediately when thrown upon the fire?

**A.** No, before any burning can commence the

coal must suffer the preparatory process of decomposition.

Q. What does the process of decomposition do with the coal?

A. It distills the gas, which ignites first and by its chemical union with the invisible oxygen of the air, forming water (or steam) after the gas is burned, the coke takes its turn and burns in exactly the same manner by combination with air forming carbonic acid.

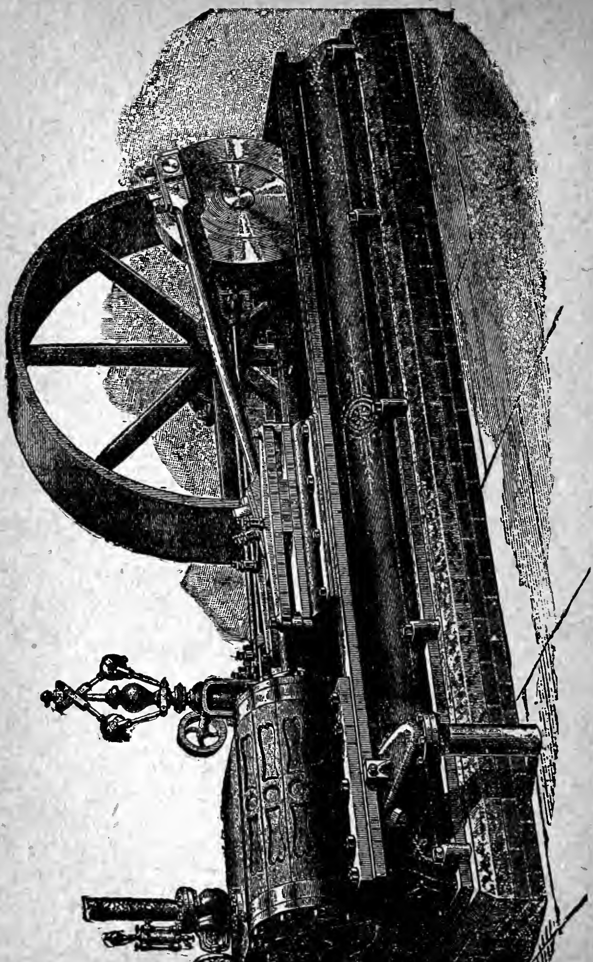
Q. What is about the total production of coal in the world at this date?

A. About 400,000,000 tons annually, one-half of which is estimated used for making steam. The average value for boiler purposes is about $2.25 per ton, which gives an annual expenditure for steam of about four and one-half million dollars, from which it will be seen how largely even a small per cent of saving would add to the wealth of the world.

## THE STEAM ENGINE.

The steam engine is a machine by means of which heat is converted into mechanical effect. The greatest economy reached in a single cylinder steam engine is 2½ pounds of coal per horse-power, per hour, (this has been reduced gradually from 10 pounds); the average engine uses 3½

pounds of coal and wastes 93 per cent. of the energy delivered to it. The greater part of this loss is in the latent heat of the steam, which is exhausted into the atmosphere or condenser, and is unavoidable so far as now known. The fact still remains that many an ordinary engine uses four times as much steam for the same power as is required in the best engines; the mechanical effect of steam in a cylinder is the product of mean pressure in lbs. and the distance through which it has passed. When steam travels "a full stroke" it exerts its greatest power; when cut off the average pressure must be taken. A large boiler is generally an advantage but it is not economy to use a large engine to develop small power. In the general care of an engine particular attention should be given to keeping the valves and piston in good condition and free from leakage, and a point of equal importance is the proper setting of the valves to admit and exhaust the steam without excessive cushion, wire drawing, etc. The use of the steam indicator is becoming very general, and in steam plants where they are applied at short intervals, any defects in the working of the engine are detected and promptly remedied, while, without the indicator, great waste of steam might continue for months without the knowledge of the engineer.



WATERTOWN—SLIDE VALVE AUTOMATIC ENGINE.

Much has appeared in print on the subject of the indicator, but as such articles are generally technical in their nature and unaccompanied by illustrative diagrams, we publish such for convenient reference of our readers elsewhere in this work.

Q. Give the proper sizes of steam and exhaust pipes for engines and pumps?

A. The steam pipe from boiler to engine should be one-quarter the diameter of the cylinder and the exhaust one-third the diameter.

Q. If your crank pin or boxes become hot, name a good cooling liquid?

A. By dropping a few drops of ammonia in with the oil will cool the journal with great surprise.

Q. At how many points does the rod push and pull on the crank pin?

A. Only one.

Q. Explain why so?

A. Because the pin turns with the disc (or crank).

Q. How much farther does the crank pin travel than the piston each revolution?

A. It travels one-third farther.

Q. How long does the piston stand still while the crank pin is making a revolution?

A. The piston stands still one-sixteenth of a revolution or one-twelfth of a stroke.

Q. When the crank pin is at half stroke, is the piston head in the center of the cylinder from either dead point?

A. No, when crank pin leaves a dead point and travels toward a half stroke, the piston

travels further than when the crank pin is traveling from a half stroke to a dead point.

Q. Give an explanation?

A. It depends upon the length of the connecting rod, whether the piston is past the dead centre or not.

Q. How do you understand the term clearance in an engine cylinder?

A. The term clearance means the unoccupied space between the valve face, cylinder head and piston head each end of the stroke.

Q. Has any engine the same power each end of the cylinder.

A. No, the end where the piston rod is connected, has the least power.

Q. Explain some of the various causes of pounding about an engine?

A An engine being out of square, lost motion in crank, cross head pin, or main journal boxes, crank pins not being square with the crank, caused by faulty workmanship, leaky piston rings, also valve unbalanced, crank discs and many others too numerous to mention.

Q. How can one tell if a crank pin or wrist pin is out of square?

A. A good spirit level will detect the slightest deviation in this and may be applied as follows: disconnect rod from cross-head; and tighten to-

crank pin so it can turn without side vibration; place the rod in a position to move freely as crank is turned, attach a spirit level to the rod with a clamp at right angles or in line with the shaft. It cuts no figure if main shaft is not properly level. The bulb in the level should not change when the crank is turned. If the wrist pin is not set squarely, the level will be tipped from side to side, as the crank turns, and the place the bulb is at different points in the revolution will show the direction the wrist takes from that of the correct position. The same answer for cross head.

Q. Give a good way of lining a shaft without removing same?

A. The better way is to use specially prepared tools, if none are handy, draw a line along the shaft about twelve inches to one side and parallel to its centre, then take an ordinary level and level shaft to line. Poorly fitted couplings and shaft often give great annoyance, it will require more power to run and no matter how much lining is done the same trouble is there.

Q. Give a good point for lining an engine?

A. Draw a seagrass line centrally through the cylinder and fasten to crank end of bed plate, then try crank pin at both dead points on line, and bring equal, then plumb at upper and lower half strokes.

Q. Explain the term cushion in a cylinder?

A. The cushion is the resistance between the cylinder and piston head by steam through the lead the valve has at the piston is reaching the dead centre or end of stroke.

Q. Give rule to measure connecting rods?

A. Find striking point in the cylinder, then mark on guides each end, then find full stroke of crank, the difference between striking points and the stroke is the clearance, divide the clearance by 2 and that is the clearance for each end of cylinder, then take measure for rods from outside centre of cross head pin and centre of crank pin.

Q. How are these measurements taken?

A. With a tram.

## THE LUBRICATOR.

Q. How is the oil delivered from the oil reservoir to steam chest?

A. Through the reach oil pipe connecting lubricator with chest.

Q. Of what use are the small valves over sight feed glasses?

A. They are to close in case of a broken glass.

Q. Are there any other valves between the lubricator and steam chest?

A. No.

Q. Why not?

A. Because there is no need of any, as the sight feed valve answers all the purpose.

Q. What do you look to when about to fill the lubricator?

A. See that the two sight feeds are closed and the steam valve between boiler and lubricator, then open lower drip first, then the filling plug to leave out water.

Q. After filling, what is done?

A. Open steam valve first.

Q. Why?

A. So as to get the boiler pressure in the condensed chamber and in oil tanks.

Q. Suppose you filled the tank with oil when cold, would you open steam valve or not?

A. Open valve.

Q. Why?

A. To have everything in working order and when the condensed valve is opened the lubricator will be ready to feed when feed valves are opened.

Q. How often should the lubricator be cleaned out?

A. It should be blown out every trip.

Q. Why?

A. So to be sure that everything is in working order.

Q. Suppose one of the sight feed glasses become broken or inoperative, can the sight feed on the other side be used?

A. Yes.

Q. Are there more than one or two sight feeds on one lubricator, if so, for what purpose are they?

A. There are lubricators with three sight feeds for locomotives, two are for the cylinders, and the third is for the steam cylinder of the air pump.

Q. Explain the workings of the lubricator, also state the weight of water and oil?

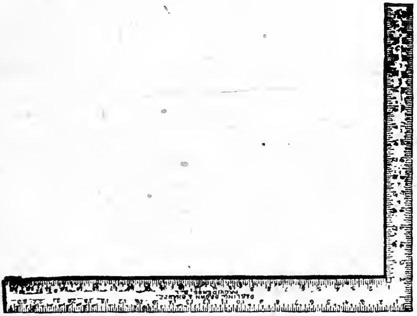
A. The lubricator is operated by the condensed water from the condense chamber above the lubricator. The weight of water is 8 pounds and the weight of oil is 7½ pounds, therefore the oil being the lighter it floats to the top.

Q. If oil floats to the top and water goes to the bottom, why is it that no water passes up through the sight feeds and the oil back up through the condensed chamber into the boiler?

A. The construction of the lubricator prevents it.

Q. Explain the construction of the inside of lubricator, oil tank, etc.?

A. The condense chamber is connected to a steam tight drip pipe from neck of condensing chamber reaching within ¼ inch of the bottom of the oil reservoir, and this pipe prevents the oil from working up into the boiler. The sight feeds are connected the opposite way, the oil pipe reaches from the top of oil reservoir to the bottom of sight feed below regulating valve.



STEEL SQUARE.

The steel square is the most valuable tool any mechanic can have. The standard square 100 has a tongue from fourteen to eighteen inches long and 1½ inches wide,

also a blade two inches wide and twenty-four inches long. The two are at right angles with each other. The square has inches, half-inches, quarter-inches, eighths, sixteenths and thirty-seconds. Another portion of the square is divided in a scale of twelfths meaning twelve feet to the inch, used for measuring drawings, blue prints, etc.

Q. What is a centesimal scale?

A. A centesimal scale is a scale for dividing a unit into one hundred equal parts.

Q. What is a diagonal scale and where is it?

A. The diagonal scale is on the tongue near blade, and is called diagonal on account of its diagonal lines.

Q. Where is the plank, board and scantling measure found on the scale?

A. It will be found on one side of the blade, running parallel with the length, and by the nine lines divided at interval of one inch into sections or spaces by cross lines.

Q. Give an example; say a board 12 feet long and 6 inches wide?

A. Look on the outer edge of the blade, we will find 12; between the 5th and 6th lines under 12, will be found 12 again; this is the length of the board. Now follow the

space along toward the tongue till we come to cross line under 6 (on the edge of blade), this being the width of the board; in the space will be found the figure 6 again, which is the answer in board measure, viz., 6 feet.

Q. Is there another style of board measure on the square?

A. Yes, on one side of the blade 9 lines, and cross lines diagonally to the right will be found and rows of figures as 7 ones, 7 twos, 7 threes, etc., this style gives the number of feet in a board according to its length and width.

Q. How does one know where to find the brace rule on the square?

A. The brace rule is two parallel lines in the centre of the tongue, one-half inch apart with figures between them. Near extreme end of tongue will be found 24-24 and to the right of these 33-95.

Q. What is meant by 24-24 and 33-95?

A. The 24-24 means the right angle—triangle while the 33-95 indicates the length of the brace, This rule explains the use of any of the brace rule figures.

Q. Where is the octagon scale to be found?

A. On the opposite side of the tongue from the brace rule, between two central parallel lines.

Q. How is the space divided?

A. It is divided into intervals and numbered 10, 20, 30, 40, 50, 60.

Q. Suppose it becomes necessary to describe an octagon 10 inches square: what would you do?

A. Draw a square 10 inches each way and bisect the square with a horizontal and perpendicular centre line.

Q. How is the length of the octagon line found?

A. Place one point of the compasses in centre of square, ond the other at corner of square, then scribe an arc from the corner of square to perpendicular line, then bisect a line at meeting point of arc and perpendicular line to corner of square, find centre of this line, the distance from perpendicular line to where centre line intersects square line, is one-half the length of each diagonal.

Q. How is the circumference of a barrel head or cylinder head divided into seven parts?

A. To divide a circle into 7 equal parts, scribe a quarter circle, then place dividers on circumference line, then scribe an arc from centre, and intersect circumference. Now draw a chord line or parallel line from the two points on circle, and the distance from centre of chord, or straight line to centre of circle is exactly one-seventh of full circumference.

## VALVE MOTION.

Q. Of what does the valve motion of a common slide valve consist?

A. The motion consists of an eccentric rocker-arm valve, valve rod, eccentric rod straps, etc.

Q. Explain the setting of a common single eccentric valve motion?

A. Move the eccentric in direction engine is to be run, until valve has proper lead, say $\frac{1}{16}$ inch, then tighten temporarily with set screws, move crank-pin over to other dead centre and see how lead is there, if equal valve is set. If not divide the difference by moving the valve with with nuts $\frac{1}{2}$ it is out on the valve gear. Then go through the same performance as in first setting and valve will come right.

Q. Give the proper exhaust for valve?

A. Double the steam lead.

### LOCOMOTIVE, LINK MOTION, VALVE SETTING.

Valve setting with two eccentrics.—Many questions have been asked in reference to setting link motion valve, so we have here clearly explained it with language easy to comprehend in questions and answers.

Q. How would you go about setting a link motion valve?

A. Adjust everything about the valve motion necessary, tram the driver for dead center of pin, and also tram the valve stem for opening point when valve chest cover is on.

Q. Suppose the engine to be set was a 18x24 inch and the upper and lower rocker-arm straight and of equal length, the eccentric blades are connected to the link, so the block in full gear is opposite, what will this equal?

A. This will make the extreme travel of the valve equal to the eccentric throw.

Q. To what should particular notice be given in commencing to set a valve with link motion and reverse lever?

A. That the eccentric blades are in straight line, and the go-ahead eccentric blade is connected to top of link and the back-up to bottom of link, also that link is about plumb and valve centrally over the ports. Place the reserve lever in forward last notch and crank-pin on forward dead center (toward cylinder); suppose lead is to be $\frac{1}{16}$ inch, move forward eccentric ahead until the tram inserts the forward punch mark on valve stem and the stationary mark on stuffing box, then tighten the eccentric temporarily, move the reverse lever to back motion (full); move driver enough to take up lost motion and bring back to dead center, forward again, and move

the back-up eccentric until the tram touches both punch-marks, and stationary and stem mark.

Q. Does the valve occupy the same position for forward and back gear when the pin is at either dead centre?

A. Yes; move the pin to back dead-centre, first placing the reverse lever in forward last notch, and tram the stem the same as where the pin was at forward dead centre. If the lead is the same for both full forward and full back notch the setting is O. K., if only one cylinder; if double cylinders the opposite side must be gone through the same way. Go over the points a second time to be sure that everything is O. K.

Q. What is meant by a blind in valve setting?

A. The lap of the valve.

Q. Suppose when the engine is turned on opposite centre and a blind is found, what does it indicate?

A. It indicates that the eccentric blade is too long.

Q. Then what is to be done?

A. Shorten the blade until the tram inserts the opening point, then move the pin over to other dead point and the valve here will be found to have lost its lead, but the valve move-

ment at each dead point has been altered thereby, so that the opening at each steam port is just beginning. Advance the eccentric to get $\frac{1}{16}$ lead, then tighten, and it will be noticed that the other end will be affected the same way, subject the opposite motion to same treatment and all will come right.

### HORSE POWER.

Q. Explain the mechanical interpretation of the unit of measure (horse power.)

A. It is generally known to be a unit of measure as applied to the steam engine, electricity or any other power that can be converted into useful effect. The term "horse power" came into effect with the building of the first engine, and it has been traced back to a man by the name of Watt.

Q. Why is it called horse power?

A. Because it was taken from the actual power of the horse, and then applied to the steam engine.

Q. How was it taken from the power of a horse?

A. The general traveling gait of a horse hitched to a light sulky is about five miles an hour or four hundred and forty feet per minute. If we were to attach to the single-tree a scale we would know the amount of actual power the horse was exerting. Suppose it to be seventy-

five pounds the product of the speed, 440; multiply $75 \times 440 = 33{,}000$ pounds, which would represent one-horse power.

Q. What would you do to apply this to the steam engine?

A. To apply this to the steam engine, first determine the area of the piston head face, next the number of feet traveled by the piston, then the average pressure used in the cylinder, and divided by 33,000 pounds, and the answer will be the horse power of engine.

Q. Would the steam gauge pressure be right?

A. No, the steam guage pressure would not be correct, but by using an instrument known as the indicator, after being attached to a cylinder, would give it exactly.

Q. Give an example.

A. Engine 30 inch stroke, making 100 revolutions per minute, the piston travels 60 inches each revolution or five feet $=500$ feet piston travel per minute, diameter of piston 17 inches $=227$ area, average pressure 40 pounds. The example then will be $40 \times 227 \times 500 \div 33{,}000 =$ $137\frac{1}{4}$ horse power, (about).

Q. Give the rule for finding the horse power of a belt's transmission?

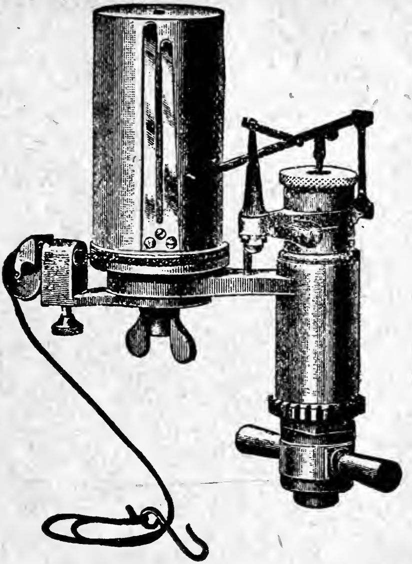
A. To find horse power that can be trans-

mitted by a belt, multiply the width of the belt in feet by the number of hundred feet the belt has traveled in one minute. Example, belt two feet wide running 2000 feet per minute, $2 \times 20 =$ 40 horse power.

Q. How is the width found if a certain number of horse power is needed?

A. Divide horse power by speed in hundreds of feet per minute, answer equals width of belt in feet.

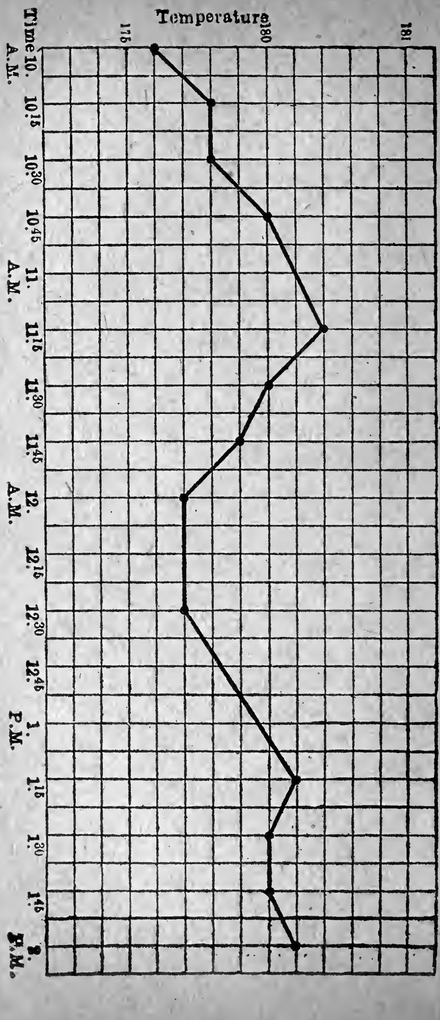
The proper and free working of a governor is an important matter for an engineer to consider. All the working surface of the governor should be in proper running condition, and such a quantity of oil used as will not gum up after it has been applied for a time. The oil pot, or dash pot, should have a constant supply of oil to retard its motion, and the oil should be heavy enough to prevent violent fluctuations. In speeding up an engine the speed of the regulator should also be changed so that the governor may work at a higher speed, and the governor weighted to bring the balls in about the same plane of station as of old. It is very frequently the fact engines are speeded up without any change in the speed of the governor.



STEAM ENGINE INDICATOR.

After the motion of levers are correctly set up, apply the indicator and obtain a diagram. It now remains to consider what this diagram is and what can be determined from it.

When the mathematician or statiscian de-


Temperature
175
180
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Time 10. A.M.
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11. A.M.
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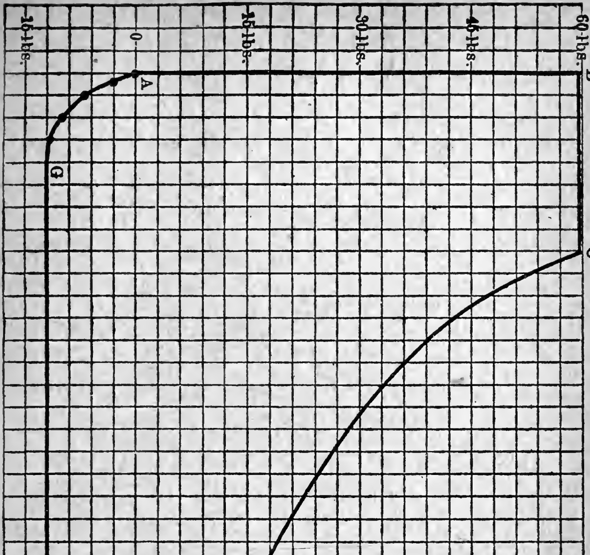
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sires to record the result of a series of observations or experiments in such a manner that they may be at once be apparent and easily comprehended, he has recourse to what is known as the graphic method. Suppose, for instance, it was desired to represent in this way the result of a series of observations of the temperature of feed water during the test; take a piece of paper ruled in squares as represented in figure 1, page 59, which is known as ordinate paper, we set off the time upon one of the horizontal lines, as shown at the bottom of the figure, and allowing two spaces for each fifteen minutes to represent one degree of temperature, making the lines so figured to correspond to 175, 180 and 185 degrees. Now at ten o'clock the observations showed 176 degrees, so upon the line representing that time and at a height representing 176 we make a dot fifteen minutes later the temperature had gone up to 178 degrees and upon the line represented 10:15 and at a height representing 178 another dot is made. Continuing in this way to represent the result of each observation and connecting the dots by lines we obtain a diagram showing at a glance how nearly regular the pressure was

maintained through the test, to what extent it varied, and at what time the variations occurred.

Let us apply this method to the variation of pressure in the cylinder of a steam engine. Suppose we have an engine with a stroke of 48 inches, cutting off at ¼ stroke, with steam at 60 pounds and a variation of 12 pounds. In figure 2, page 60, let the line o represent the pressure of the atmosphere; i.e., the zero pressure of a steam gauge, and set off upon it 48 spaces to correspond with the 48 inch stroke of the engine. Now, at the beginning of the stroke at A, steam is admitted, and calling each vertical division 3 pounds we set off 60 pounds upon the line A, B; this pressure is supposed to be maintained for a quarter stroke, and thus for 12 of the horizontal divisions the pressure would be represented by the horizontal line B. C. At the point C the supply of steam to the cylinder is cut off and the pressure behind the receding piston falls by expansion. The pressure for any position of the piston can be easily calculated by a method which will be explained at the proper time. Placing upon the vertical lines representing each inch of the stroke a dot representing a

corresponding pressure and connecting these dots we have a curved line representing the variations of pressure during expansion, at the point D, two inches from the end of the stroke, the exhaust valves supposed to have opened for release, allowing the pressure to gradually fall along the line D, E, F, to that of the condenser, 12 pounds below the atmospheric line. This is the pressure which should be before the piston on its return movement up to the point G, four inches from the end of stroke where the exhaust valve is supposed to have closed for compression, and the pressure of the enclosed steam is raised along the curve G, A.

Now, the steam engine indicator applied to this engine would produce a diagram more or less approaching this theoretical form, the pressure being measured by the vertical movement of the indicator piston and the piston movement of the engine by the movement of the paper drum which is directly derived from it, as heretofore described. It furnishes us with a graphic representation of the distribution of pressure in that end of the engine cylinder to which it is attached for a complete revolution. By its means we are able to see at once whether

the various operations occur on time with reference to the piston movement, how nearly the boiler pressure is realized in the cylinder; at what point it is cut off and how much benefit the engine derives from the vacuum in the condenser. We are also furnished with the necessary data for calculating the average pressure of the piston during the stroke, and from this determine how much work it is doing, and as the distribution of this pressure is apparent we are able to calculate its rotative effect upon the crank-pin at any point in the stroke in connection with the momentum and inertia of the reciprocating parts.

In fact a properly taken diagram with all data concerned is full of interest and instruction, and its study can be carried to great refinement. The most simple rule for figuring the diagram is to set down the length of the spaces formed by the vertical lines from the base in measurements of a scale accompanying the indicator, and on which a tenth of an inch usually represents a pound pressure; add up the total length of all the spaces, which will give the main length, or the main pressure upon the piston in pounds per square inch. Example, lay the indicator

card off in ten parts, and knowing the scale to be sixty, and the ordinates (or parts) ten, and the sum of their length, six inches=6-10 .6×60=36.0 36 pounds pressure against piston.

Q. How do we understand the horse power of an engine.

A. The horse power of an engine is equal to lifting 33,000 pounds one foot high in one minute.

Q. How is the horse power calculated? Give various simple rules.

A. Rule one, multiply the area of piston head face in square inches by the steam pressure in pounds, and the answer by the travel of piston in feet per minute, and divide by 33,000. This will give the nominal horse power. For actual horse power deduct ⅓ in automatic and ½ in slide valve engines. Example: engine 12×24, speed 100 revolutions per minute, boiler pressure, 80 pounds piston area, 113 square inches×80=9,040×400, feet traveled=3,616,000 ÷ 33,000=109 nominal horse power, or 73 actual horse power, in automatic cut off engines, or 54½ horse power in slide valve engines. This reduction is made for friction, average pres-

sure, condensation, etc., and is found to be quite correct in practice.

To find horse power to elevate water a given height.

Total weight of water in pounds multiplied by height in feet, divided by 33,000, equals horse power.

## LOCOMOTIVE BREAK DOWNS.

Q. How and when do you block the crosshead when disconnecting?

A. Ports should be covered first, before blocking crosshead. With some of the mogul engines the crosshead should be blocked in front end of guides on account of piston rod key being so long and catching the pin on forward driver. Some of the mogul engines, with all side rods down, key in crosshead will strike pin on front wheel.

Q. How do you keep the packing rings out of the counter bore?

A. When disconnecting, I would put a small piece of wood between end of cross-head and end of guides.

Q. Would you take out the cylinder cock at the end piston is in?

A. Not necessarily, if the crosshead is well blocked.

Q. What would you do if main rod strap or crosshead should break?

A. With a broken main rod strap, I would place valve over steam ports and clamp valve stem, disconnect valve rod, take down main rod and broken strap, and block crosshead. If crosshead broke and did not come off piston rod, would block it in back end of guides. If piston broke off crosshead, would push crosshead and piston to forward end of guides and block it there, if it did not knock out cylinder head.

Q. What is done if side rod or back pin breaks?

A. If side rod or back pin breaks, take down both side rods.

Q. Can all four-wheeled switch engines be run with the side rods down?

A. No; on some switch engines the eccentric is on the forward shaft, and the main rod connected to the back wheels. On some of them, with both side rods down, a crosshead key would strike the pin on the front wheel and would have to be cut off or else driven out, and a liner put in alongside of the key, so as not to allow it to go through too far.

Q. Why do you take rods down on the opposite side to that broken?

A. Because if left up, and the engine should slip, the back wheels while on the center are liable to slip out of tram and break the rod or pin.

O. What is the effect of sanding the rail while engine is slipping, without first shutting off steam.

A. It is liable to break a crank pin or rod.

Q. Is it good policy to allow sand to run from one pipe only?

A. No; it is liable to twist the driving axle or break a pin. The adhesion of the engine to the rails is nearly all on one side, and has a tendency to twist.

Q. How do you block up an engine with a broken driving spring or hanger?

A. If main spring was broken, or hanger, run back wheels up on wedge, and block between main box and frame, then move back wheel off wedge and run main wheel upon wedge and block end of equalizer up level, and take out broken parts of spring and hanger.

Q. With broken equalizer?

A. Would take out broken equalizer and

springs, and block up the same as with broken driving spring.

Q. With broken engine truck, spring, or hanger?

A. Would raise front end of engine up, and block up on top of truck equalizers.

Q. With broken intermediate equalizer on mogul?

A. Would run main drivers up on wedges, then block between top of forward driving boxes and frame, then take out broken parts of equalizer.

Q. With broken engine truck center pin on mogul, what is to be done?

A. Would block up, the same as with intermediate equalizer, but, in addition to this, would have to block up forward end of intermediate equalizer to keep it off truck axle.

Q. What do you do when a tire breaks and comes off the wheel on a standard engine?

A. If tire broke and came off main wheel and did not injure the rods, would leave rods up and take out oil-cellar, take down pedestal brace and put block of wood up under shaft, putting brace up again, then run main wheel up on wedge, then block up between

top of back box and frame and block between main-spring saddle and frame, then run wheel off wedge, and you are ready to go. With back tire broken off, if the engine had to be backed up any distance on crooked track, would take both side rods off and carry both back wheels off the rail by running them up on two wedges and block up on top of both main boxes under frame, and block under both back-spring saddles and put a block on top of bar between engine and tender and under chaffing iron on engine, and carry part of the weight of engine on tank, and would block under both oil-cellars.

Q. With front tire on mogul or ten-wheel engine?

A. If broke front tire of mogul, and it was not safe to run, and could not get tire off, would take down all side rods then run front wheels up on wooden wedges and block up on top of both main boxes under the frame and under both spring saddles on top of frame and block under male casting of engine truck and on top of female casting; some large nuts would be the best to use to block up between these castings; take a piece of telegraph wire and run through

holes in the nuts and fasten them solid around the male casting, and drive block under each oil-cellar of the wheels which are carried off the rail and move engine off the wedges and you are ready to go.

Q. Main tire on mogul?

A. If main tire on mogul broke and came off and injured side rods or main rod, would take down all side rods and place valve over steam ports, clamp valve stem, disconnect valve rod and take down main rod, and if piston rod key would strike front pin, would block crosshead in forward end of guides, would take oil-cellar out of wheel with tire off, take down pedestal brace, and put a hardwood block under shaft, then put pedestal brace up again, run wheel up on wooden wedge and block up on top of back box under frame, and on top of front box under frame, and block between saddle and frame over wheel that is off the rail, then run engine off the wedge and you are ready to go. If tire is broken and it is not safe to run and could not be gotten off on the road, would take down all side rods; if I could run the engine on the wedges, would run both wheels up and block up on top of both back boxes under frame and on top of both

front boxes under frame, drive a block under each oil-cellar and block under both main spring saddles, then cover steam ports on both sides and clamp valve stems and disconnect valve rods, take down both main rods, and if piston rod keys will strike front pins, block the crosshead in front end of guides, or the center of guides, and you are ready to be towed in. Engine will have to be moved off from wedges with another engine or pinch bar.

Q. With the back tire on mogul?

A. If back tire on mogul broke and came off and did not injure side rods, would take out oil-cellar and put wooden block under shaft, then run wheel up on wedge and block between top of main box and frame, then move engine off wedge and you are ready to go.

Q. With both back tires on mogul?

A. If tire broke and did not come off, and you could not get it off on the road and it was not safe to run, would take down both back sections of side rods and run both back wheels up on wedges, block up between both main boxes and frames, then block on top of bar between engine and tender under chaffing iron on engine, drive a block under

each oil-cellar and block under both back spring saddles and you are ready to go. You could not back up around curves on account of both main tires being blind. If I have to back an engine up to get home, I would run her ahead to the nearest turntable or "Y" and turn around if it was not too far. If I could get to a turntable or "Y" by backing up two or three miles, I would drop the wheel with the broken tire on the rail and cut a pole and put it between the spokes of the wheels and against the frames and skid back wheels; If I could not get a pole, I would use a chain; If both tires came off the wheels, would chain from end of frame to front beam of tender on each side and the tender would help to guide the wheels.

Q. What would you do if back tire or back driver was broken off on standard engine?

A. Would jack up back, take down side rods on standard engine, or back rods on mogul.

Q. At what points is weight of engine carried when springs and equalizers are in good order?

A. The weight is carried on both equalizing stands and center of engine truck.

Q. Where is the weight carried when engine is blocked up over the forward driving box?

A. When blocked over the main box the weight is the same as with the main spring in, but when the engine is in motion and the main wheel drops in a low spot in the track the weight of the main box is carried on the back spring and engine truck, and if main wheel runs up on a high spot in track, the main box would take the weight off the back spring and engine truck. The equalization of the weight between the boxes is destroyed when blocked over the boxes when the engine is in motion.

Q. How is it when blocked over back driving box?

A. When blocked over the back driving box, the weight is the same as with the springs in, but when the engine is running and the back wheel drops in a low spot in the track, the weight from off the back box comes on the main spring and engine truck. And if main wheel runs up on a high spot in the track the most of the weight would be on main spring alone. And if main

wheel drops in a low spot the weight would be on back box and engine truck.

Q. If truck axle was bent?

A. Slide the wheels by chaining same.

Q. How would you know if valve yoke was broken?

A. Place main pin on right side at half stroke (giving valve full movement over ports), admit a little steam into the chest and move the reverse lever forward and back, if steam shifts from forward to back cylinder cocks the right valve yoke is O. K. Then try the left side the same way. If yoke is broken, take off chest cover, center and block valve equally over both ports, disconnect the main and valve rods, block crosshead, cover chest and proceed to nearest side track or telegraph station.

Q. If throttle was detached while running how would you act?

A. If valves were balanced, would control train with reverse lever and air valve.

Q. Suppose right go-ahead eccentric slipped what would you do?

A. Place right side of engine on forward dead center, place reverse lever in last back notch, mark valve stem at gland, bring reverse lever to forward last notch and move

slipped eccentric until mark on valve stem reaches gland.

Q. If right back-motion eccentric should slip?

A. Place right side of engine on back dead center, place reverse lever in forward last notch, mark valve stem at gland, throw lever in last back notch, move eccentric until mark on valve reaches gland.

Q. Suppose both forward and back eccentric on one side slipped what would you do?

A. Simply place engine on forward dead center (as near as possible), set the forward motion eccentric above the shaft heavy side up, for in right angles with the crank-pin, set the back-up eccentric opposite the go-ahead; after this is done place the reverse lever in forward notch, then move the forward eccentric ahead until steam comes out of forward cylinder cock. To set back-up eccentric, place reverse lever in last back notch, move eccentric until steam comes out of forward cylinder cock, then all is O. K. Be careful when doing this, that engine wheels are blocked and throttle slightly open.

Q. In case of broken back section of side

rods on a 6 driver engine, what would you do?

A. Take off back sections, each side of engine, then pull in as much of the train as possible.

Q. Suppose through some unforseen cause a cylinder head was broken what would you do?

A. Disconnect the valve stem at rocker arm, tighten valve equally over ports, disconnect mainrod and block the crosshead in guides.

Q. Suppose rocker arm is broken?

A. Disconnect same as for broken cylinder head.

Q. If valve stem or piston were broken?

A. Do same as for broken cylinder head.

Q. Suppose valve in chest were broken how would you remedy it?

A. Lift valve chest cover, cover ports with thin plank, place valve over same and block that way; if a balanced valve and nothing could be placed under valve then open front end and disconnect dry pipe from nigger head end, bolt on a blind joint made of sheet rubber and heavy board or iron plate.

Q. Suppose you lost a rod key how would you proceed?

A. Insert a wooden key temporarily.

Q. If broken valve stem outside of chest?

A. Center valve and clamp with gland by drawing up more on one side.

Q. What is the best material to use in blocking between driving box and frame?

A. Iron plates; wood is too soft.

Q. If driving box or brass breaks so it is cutting the axle, what can be done to relieve it?

A. If main box brass is cutting badly, run main wheel upon a wedge, and block under saddle and on top of frame, also between frame and top of back box, that will carry some of the weight.

Q. Is it considered an engineer's duty to have suitable hardwood blocks on engine?

A. Yes.

Q. How would you block up for broken engine truck wheel or axle?

A. Raise up front of engine and block between top of main boxes and frames and block on top of back truck boxes under truck frames and block across on top of both back truck boxes under main frames and carry the weight of the front wheels on the back ones and forward drivers, then chain front wheel up to front frame; then pull into

side tracks, best way is to send for pair of wheels and put in on road.

Q. What would you do with a mogul or a pony truck when broken?

A. Would run main wheels up on wedges, being careful that main rods do not strike guide yokes and frames, then chain engine truck up to main frame and all is ready.

Q. For broken tender truck wheel or axle what should be done?

A. Take out wheels and replace with box-car wheels, or if wheels could not be had, why take two poles and lay them lengthwise on top of the truck boxes on each side of tender and chain up the truck to the poles where the wheels come out. With some tenders, would have to put pole across top of tender and chain to pole.

Q. Is it necessary to take down the main rod if the frame is broken between the cylinder and the forward driving box?

A. No, not always; it all depends on how badly it is broken.

Q. Would you take down either rod if frame is broken between forward and back driving boxes?

A. Not with a light engine, unless it was working badly; then I would take down both

side rods, because the strain would come on the pins.

Q. Where is the frame fastened solid to the other parts of the engine?

A. On standard engine frame is fastened to cylinder saddle, and belly-brace under boiler, and boiler braces in cab.

Q. Would you disconnect the engine for a broken guide?

A. Yes, if it was broken badly.

Q. How do you handle an engine if throttle sticks open or dry pipe joint leaks so that steam cannot be shut off from engine?

A. Reduce the pressure and handle the engine with reverse lever and brake on engine.

Q. What will you do if throttle is disconnected and remains shut?

A. I would report and get her ready for towing in.

Q. If a crank pin brass gets so hot the babbitt melts, would you cool it off with water before all the babbitt comes out?

A. No, I would allow it all to escape.

Q. Can you take out a tender truck brass and replace it with a new one? How?

A. Yes; would take waste all out of box. take short jack and put under box and jack

the weight up off brass, then take out step and remove brass. If I had no short jack, would take large screw jack and place under side of tank and jack the weight off box, then take a pry and pry up the box. If I had no jacks I would put block of wood under the box and against a tie and move the engine and pull the box up on the block, and that would take the weight off brass.

Q. An engine truck brass?

A. Would raise up front of the engine, and take weight off truck box, then raise up truck frame and box with short jack or a pry, and replace brass.

Q. When brass does not wear an even thickness at both ends, is it apt to run hot? Why?

A. Yes; truck frame may be twisted, and allow the weight to bear on one end of the brass, and cause it to heat, axles sprung lightly would cause this effect, or only part of a step being on top of brass in box, or brass a little too long and one end bears on collar.

Q. How often do you examine the ash-pan, grates and dampers?

A. At the end of every trip.

Q. What are your duties after cutting off from train at the end of the trip?

A. To look the engine over carefully, and any work there is to be done, report it in the book at the roundhouse for that purpose.

Q. What are your duties in case of wreck, when your engine is off the track?

A. Examine the engine over carefully, to see if anything is broken, especially around firebox, and get her ready to be put on the track as soon as I possibly could.

Q. If front end is broken, but flues and steam pipes in good order, how could you make repairs on it to run in?

A. Would board up front end of smoke box if there was enough left to hold the boards.

## THE AIR BRAKE.

Q. To the best of your knowledge what do you understand by the automatic air brake?

A. The automatic air brake is a brake applied by compressed air.

Q. Why is it called automatic?

A. Because its application is due to derangements, such as the bursting of a hose

or pipe, train broke in two, the trainmen reducing the air pressure in train pipe, or the engineer making a reduction of air with his brake valve.

Q. Give an explanation of the automatic brake, its workings and essential parts?

A. The essential parts of the automatic air brake is the engineer's equalizing discharge valve, auxiliary reservoir triple valve, small reservoir at the side of the engineer's equalizing discharge valve, the trainmen's application valve, the steam, air pump and governor, air guage, air pipe, cock, etc.

Q. Of what use are the steam and air cylinders?

A. They constitute the air pump, and are used for compressing air into the main reservoir.

Q. Of what use is the main reservoir?

A. It is used to retain and carry the air pressure pumped in with the air pump.

Q. Of what use are the auxiliary drums?

A. They are used to hold and furnish air for the brake cylinders when brakes are to be set.

Q. Explain the triple valve and its location?

A. The location of the triple valve is

between the brake cylinder, train pipe and auxiliary reservoir and is used to let in or out or hold the air between the auxiliary reservoir and brake cylinder.

Q. For what purpose is the small reservoir that is connected to the equalizing discharge valve?

A. It is to store air pressure to force the equalizing piston down when sufficient air has been released from brake pipe, to automatically close exhaust.

Q. Where is the air first taken from when making service stops.

A. From the main train pipe.

Q. Where next?

A. From the auxiliary reservoirs under each car, which passes through the triple valve into the brake cylinder.

Q. When an engine is left standing alone and the pump running, why must the brake valve not be left on lap?

A. Because the main reservoir pressure may run up to the same height as the steam in the boiler, and when the handle of engineer's valve is again placed in full release it will cause the train pipe and tender auxiliary reservoir to be charged with too high pressure, and may injure the

adjustment of pump governor as well as cause the tender wheels to slide on first application.

Q. What position is proper?

A. Running position.

Q. Have brake cylinders what is called leakage grooves?

A. Yes.

Q- As a rule how much air is necessary to be discharged from train pipe to force the piston past the leakage grooves?

A. About 5 lbs.

Q. How long are the leakage grooves in the brake cylinder?

A. Four inches.

Q. Where are they located?

A. In forward part of cylinder.

Q. What are the leakage grooves provided for?

A. They are provided to release the brake cylinder of any air that might leak into it throngh the triple, also release the air left in brake cylinder after an application has been made.

Q. Name the different positions of the equalizing discharge valve?

A. There are five, namely: full release,

running position, on lap, service top, and emergency.

Q. Why is equalizing discharge brake valve better than the old brake valve?

A. Because it enables the engineer to apply the brakes more uniformly throughout the train, and with less shock, especially when quick action triple valves are used. It also prevents the brakes on forward end of train from being kicked off when engineer closes the valves after having made application.

Q. Name the different kinds of engineers' brake valves, to the best of your knowledge.

A. The D 8 and D 5.

Q. What divides the main reservoir pressure from the train line pressure?

A. The equalizing discharge valve.

Q. On which side of the equalizing discharge valve is the main reservoir pressure?

A. On top.

Q. On which side of the rotary valve in the old-style engineer's valve is the main reservoir pressure?

A. Below.

Q. What air pressure operates the pump governor in the D. 5 and D. 8 valve.

A. With D. 5 brake valve the main reser-

voir, and with all others the train pipe pressure.

Q. Suppose the governor does not regulate the train line pressure, how would you adjust it with the D. 8 valve, also the D. 5?

A. With D. 8 valve the train line pressure is regulated by the pump governor, the spring in governor should be set so 70 pounds of air pressure will raise the diaphragm and air valve, so air will go down on governor piston and force the steam valve shut. With the D. 5 valve the train line pressure is regulated by the feed valve or train line governor on the side of brake valve. Set spring in feed valve so it will let the train line pressure move feed valve piston down with 70 pounds pressure, this will let feed valve close so no more air can pass from main reservoir through running position port to train line, and pump governor should set at enough higher pressure to carry the desired excess pressure.

Q. Why is governor regulated to only allow 70 lbs. of air pressure in train pipe?

A. Because 70 lbs. train pipe pressure produces the strongest, safe to use and prevents sliding of wheels.

Q. Explain the difference between the plain and quick action triple valves?

A. The plain triple valve has the cut-out cock in the body of the valve; the quick-action has it in the cross-over pipe between the train pipe and triple. The plain triple does not have the additional parts to work the emergency action of the triple, consequently the brake is not liable to leak either on or off through the emergency valves or checks. The plain triple used on engine tender and coach equipment is so arranged that the piston works upright, and when the train is running the jar may work it down, and cover feed port so a very light reduction will set it; the piston in quick action triple moves horizontally, so its weight does not influence the action of the triple when running.

Q. What might prevent governor from shutting off the steam and stopping pump when maximum pressure is obtained?

A. The engineer's brake valve being on lap.

Q. If the piston in equalizing discharge brake valve becomes corroded and gummed what will be the result?

A. It would be necessary to make a large

reduction through the preliminary exhaust port before the brakes will apply at all and then the brakes will go on too hard and will have to be released by hand.

Q. At what travel should a driver brake piston be adjusted?

A. Not less than ⅓ or more than ⅔ its full stroke.

Q. How is the brake-shoe slack of the cam driver brake taken up and what precautions are necessary?

A. By means of the cam screws, and it is necessary to lengthen both alike, so when brake is applied the point of contact of cams will be in straight line with piston rod.

Q. How is the brake-shoe slack of a six-wheel connected driver brake taken up?

A. By means of a turn buckle or screw in the connecting rods.

Q. How would you take up slack of tender brake shoes?

A. By means of the dead truck lever.

Q. Suppose they would not take it up enough; where then?

A. It must be taken up in the underneath connections and then adjusted by the dead lever.

Q. What distance should the brake cylinder piston travel under tender brake?

A. Not less than 5 nor more 6 inches; adjustments must be made whenever the piston travel is found more than 7 inches.

Q. How often should triple valves and cylinders of drivers and tender brakes be cleaned and oiled?

A. Every 6 months with mineral oil; oil cylinders every 3 months, and driver brake cylinders oftener if close to fire-box.

Q. How often must the air brake and signal apparatus on locomotives be examined?

A. After each trip.

Q. What pressure of air must be carried on passenger engine and main train pipe?

A. 70 lbs.

Q. On freight?

A. 70 lbs.

Q. What should the excess pressure be, also the signal pressure?

A. Excess pressure is 20 lbs., and signal pressure is 25 lbs.

Q. Do you understand the necessity of keeping the feed valve and excess spring clean?

A. Yes, so it will maintain an excess pressure of about 20 lbs., in the main reser-

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voir and to insure release and recharge train quickly.

Q. Why is excess pressure necessary?

A. It is to recharge auxiliary reservoirs quickly.

Q. After the engine is backed up to train what should be done?

A. The air cock should be opened and the hose blown out, then connect to train hose, after that the engineer's brake valve should be placed in the release position, so train pipe, auxiliary reservoir and main reservoir come in connection and equalize with air.

Q. What is next to be done?

A. Test the air and brakes to see that all parts are in order before starting out on a run.

Q. Suppose the pipe between brake cylinder and auxiliary reservoir was split or broken off, and prevented the operation of the triple valve, what should be done?

A. Move triple valve midway and open bleed cock under auxiliary reservoir.

Q. Will that interfere with the rest of the train?

A. No.

Q. About how much loss of air out of

train pipe is considered to firmly set all brakes?

A. Generally about 18 or 20 pounds.

Q. Suppose after having recharged the train pipe from main reservoir and released all the brakes but the one under tank, where would you look for trouble?

A. Examine triple valve and see if it is up, if not, then move up and equalize air.

Q. Give the different forces with different cylinder diameters and the brake piston traveling at eight inches in all?

| Pressure in Brake Pipe. | Exhausted from Brake Pipe. | Pressure on Brake Cylinder Piston. | Total Force From Piston, in Pounds. | | | |
|---|---|---|---|---|---|---|
| | | | 14-in. Cylinder. | 10-in. Cylinder. | 8-in. Cylinder. | 6-in. Cylinder. |
| 70 | ...... | ...... | ...... | ...... | ...... | ...... |
| 63 | 7 | 4 | 600 | 300 | 200 | 100 |
| 61 | 9 | 19 | 1900 | 1500 | 950 | 500 |
| 59 | 11 | 26 | 4000 | 2050 | 1300 | 700 |
| 57 | 13 | 40 | 6150 | 3150 | 2000 | 1100 |
| 55 | 15 | 46 | 7100 | 3600 | 2300 | 1500 |
| 53 | 17 | 50 | 7700 | 4000 | 2500 | 1400 |
| 51 | 19 | 50 | ...... | ...... | ...... | ...... |
| 49 | 21 | 50 | ...... | ...... | ...... | ...... |
| 47 | 23 | 50 | ...... | ...... | ...... | ...... |

Q. Is there a limit to the braking power of the automatic brake?

A. Yes.

Q. What governs it?

A. The triple valves, graduating valve.

Q. Can you tell by the gauge when this limit is reached?

A. Yes.

Q. What pressure is in cylinder when 70 lbs. pressure is in auxiliaries?

A. 50 lbs.

Q. What are the functions of the triple valve?

A. It is to automatically open and close the auxiliary reservoir valve when pressure is increased and decreased in main brake pipe.

Q. Why is it called a triple valve?

A. Because it connects and operates three points, namely: main train pipe, auxiliary reservoir and brake cylinder.

Q. Where is the compressed air kept ready for use?

A. In the main reservoir about engine.

Q. Where does the compressed air come from that enters the brake cylinder when the automatic brakes are applied?

A. It comes from the auxiliary reservoir.

Q. How does it get into the auxiliary reservoir?

A. From the main train pipe through the triple valve.

Q. About how many seconds does it take for the auxiliaries to recharge with air?

A. About two seconds.

Q. When two or more engines are coupled together, which one should do the braking?

A. The head engine.

Q. How would you proceed to give the forward engineer complete control of the train?

A. Engineer on second engine must close stop cock under his brake valve leading to train pipe, place brake valve in "running" position so as to give leading engineer full control of the train. Second engineer must keep maximum pressure up in main reservoir to use in case head engine gives out.

Q. What should the leading engineer do?

A. Make a terminal test of train, etc.

Q. What is the pressure retaining valve, and what is its use?

A. The pressure retaining valve is at the exhaust of triple valve. It is used to prevent the brake release on heavy grades and hold the brakes partially applied so as to allow more time to recharge the auxiliary reservoirs.

Q. How much pressure does the pressure retaining valve keep in brake cylinder?

A. It retains 15 lbs. pressure in brake cylinder when triple valve is in release.

Q. In descending a grade how can you best keep a train under control?

A. Apply brakes and reduce speed before too much speed is attained; keep a reduction of 8 pounds of air on train pipe, then recharge the auxiliary reservoir so to have air when needed.

Q. Suppose the air pump should happen to play out descending a long steep grade, with from 30 to 50 cars of air, how could you keep up the pressure in main reservoir, and the air pump stopped entirely?

A. By what is known as Sweeney's emergency brake.

Q. Explain what is meant by Sweeney's emergency brake?

A. On the steam chest of cylinders is a small valve with a rod running from its handle back under the running board to cab. This merely connects the steam chest, by means of a pipe, to the main air drum; in descending a hill and no steam being used, simply open the valves to the Sweeney auxiliary pipe and reverse the engine both

pistons of the engine pumps air into the main reservoir and very fast. In this way an engineer can keep his full drum pressure up easily by letting the cylinders help him out occasionally.

Q. Would you reverse an engine with driver brakes set?

A. No.

Q. Why not?

A. Because it would block the drivers and cause flat wheels.

Q. Why are three lines of hose coupled between the engine and tender on some of our engines?

A. One for main train pipe, one for air signal and the third for steam to heat train, etc.

Q. Why only two on some engines?

A. One for main train pipe and one for air signal.

Q. Why only one on some engines that have both driver and tender brake?

A. The one hose covers all on main train air pipe.

Q. In case the lines of hose are coupled up wrong between engine and tender, can the brakes be worked?

A. No.

Q. How will you detect the ones that are coupled up wrong?

A. First, try to release the brakes; if they will not release they are wrong; couple properly, then test air signal; the last is bound to be O. K.

Q. What must be done with the hose coupling back of last car and at pilot?

A. They should be hung in the dummy coupling.

Q. State the importance of this.

A. It is done to keep out dirt, also to prevent the hose from being torn or pulled off, etc.

Q. When engineer's brake valve is on lap position and the main reservoir or train line pressure increases, where would you locate the trouble?

A. Locate the trouble at the rotary valve, being cut or leaky.

Q. How often should the engineer's brake valve be cleaned, oiled and looked after?

A. About every 60 days.

Q. If there was a continuous leak from exhaust of triple valve, what would be the trouble?

A. Dust or dirt getting in on the road.

Q. Could you remedy it on the road?

A. Most generally, by suddenly opening and closing triple valve the air will clean it.

Q. When does the triple valve move?

A. When the engineer moves the engineer's valve to the full left the train pipe is put in connection with the main reservoir valve and lets the air from the main reservoir into the brake pipe, the triple valve moves up, equalizes the pressure between the auxiliary reservoir brake pipe and main reservoir; this opens the brake cylinder valve and releases the brake.

Q. What would happen if the engineer moved the engineer's valve handle between the two laps, closing the main reservoir valve and letting the air out of the brake pipe?

A. The triple valve would move down and connect the auxiliary reservoir to the brake cylinder and apply the brakes.

Q. State the object of having two needles on air gauge, also the two colors, red and black?

A. The red needle is to show the main reservoir pressure and excess of 20 lbs. = 90 lbs., the black one is to show the mount of air in train pipe, 20 lbs.

Q. What do you consider an ideal manner of breaking?

A. Move engineer's brake handle to service stop position until the train pipe needle shows a loss of about 8 lbs.; then move handle in lap, and gradually bring the reduction down to 20 lbs. and hold there until about to stop, then release just before stopping; on a heavy grade keep brakes on.

Q. In making service stop, why release the brakes before coming to full stop?

A. To prevent sudden shock to passengers and train.

Q. Is it dangerous to apply and release brakes more than once in making stops?

A. Yes. Because every time brakes are released the air in brake cylinders is wasted, and if necessary to suddenly apply again for some unforseen cause, before sufficient time has elapsed to re-charge auxiliaries, the application will be weak.

Q. In making a service or regular stop why must the brake valve handle not be moved past the position for service application?

A. Because in doing so the air would all be lost.

Q. Why is it dangerous to apply and release the brake repeatedly in making a service stop?

A. Because in so doing the air would be lost.

Q. In releasing brake how long should the handle be left in the same position?

A. Until the train pipe needle shows the same pressure as main reservoir, then move handle in running position against stop.

Q. What is meant by a terminal test?

A. It means to try the air and see that all is O. K. before going on a run.

Q. Why is it absolutely necessary?

A. Because all the auxiliary reservoirs must be equalized in pressure with main reservoir, that all couplings are correct, and that the brakes work satisfactorily.

Q. At what other times should tests of the same nature be made?

A. When a car is picked up on the road or one in the middle of the train is thrown out, or any switching, etc., is done.

Q. In picking up uncharged cars what should be done?

A. After coupling to car move the handle of brake valve in release, so to fill auxiliary

reservoir when cocks are opened between the cars.

Q. Why are brakes released before uncoupling cars?

Q. If train was broken in two, how would you proceed to get under way again after coupling up, and what would you do?

A. Place brake handle on lap and leave it there until train has stopped and the brake apparatus has been examined and a release signal is given, after coupling up again await signal to test brakes after having charged aux reservoirs.

Q. How would you get the train ready?

A. Place handle of brake valve in full release, then in running position, then await test signal, then test brakes, etc.

Q. Would it be necessary in this case to make what is called a terminal test?

A. Yes.

Q. Why?

A. To be sure everything about the braking power is O. K.

Q. Suppose trainmen cut out a car, what should be done?

A. The handle of engineer's brake valve should be moved into full release to equalize the auxiliaries and train pipe.

## SPEEDING AND SIGNALS.

Q. Give as near as practicable the distances of telegraph poles, also how many to the mile.

A. The telegraph poles are supposed to be 165 feet apart, and 32 poles to the mile.

Q. Suppose you were running 45 miles per hour how many minutes and seconds would you allow to each mile?

A. One minute and 21 seconds.

Q. To 25 miles?

A. Two minutes and 24 seconds

Q. To 10 miles?

A. Six minutes.

Q. To 58 miles?

A. One minute and 2 seconds.

Q. To 30 miles?

A. Two minutes.

Q. To 35 miles?

A. One minute and 42 seconds.

Q. To 15 miles?

A. Four minutes.

Q. To 55 miles?

A. One minute and 6 seconds.

Q. To 40 miles?

A. One minute and 30 seconds.

Q. To 20 miles?

A. Three minutes.

Q. To 50 miles?

A. One minute and 12 seconds.

Q. To 60 miles?

A. One minute.

Q. How would you find the time it would take to travel a certain distance, making a certain speed per hour?

A. Multiphy the distance by 60 and divide by rate of speed.

Q. Give an example: A train running from station to station, say distance is 8½ miles, and the rate of speed is 28 miles per hour, how long will it take to make the 8½ miles?

A. 8½ miles × 60 = 510 ÷ 28 miles = 18⅓ minutes.

Q. Can you give the distance and the time to find the rate of speed?

A. Yes. Multiply the distance by 60 and divide by the time?

Q. If it takes a train 18⅓ minutes to run 8½ miles at what rate of speed does the train run?

A. 8½ miles × 60 minutes = 510 ÷ 18⅓ = 28 miles per hour.

Can you give the time and the rate of speed to find the distance?

A. Yes. Multiply the time by the rate of speed and divide by 60.

Q. If the train is running at the rate of 28 miles per hour of $18\frac{1}{3}$ minutes what is the distance passed over?

A. $18\frac{1}{3} \times 28 = 510 \div 60 = 8\frac{1}{2}$ miles, the number of miles passed over in $18\frac{1}{3}$ minutes at a speed of 28 miles per hour.

To those who prefer to use formula, I give the following:

Let T=Time in minutes.
R=Rate of speed, in miles, per hour.
D=Distance in miles.
60=Constant.

I. Given, R and D, to find T.
Solution: $\frac{60}{R} \times D = T$.
II. Given, D and T, to find R.
Solution: $60 \div \frac{T}{D} = R$.
III. Given, T and R, to find D.
Solution: $T \div \frac{60}{R} = D$.

Q. How do you understand the

## SIGNALS IN GENERAL.

### BELL-CORD OR ENGINEER'S AIR WHISTLE.

One tap when standing still—Go ahead.
Two taps when running—Stop.
Two taps when standing—Call flagman.

Three taps when standing—Back up.

Three taps when running—Stop next station.

Four taps when running—Reduce speed.

## ENGINE WHISTLES.

One long whistle, stations, draw bridges, junctions and R. R. crossings.

One short whistle—Stop, on brakes.

Two medium whistles—Start, off brakes.

Two short whistles—Answer to all signals except when broke in two.

Three long whistles—Train parted.

Three short whistles when standing—Back up.

Three short whistles when running—Call attention to signals carried.

Four long whistles—Calls in flagman.

Four short whistles—Switch or signals.

Two long and two short whistles—Wagon-road crossing.

Five short whistles—Send out flagman.

Continuation of short whistles—Stock on track.

## LAMP AND HAND SIGNALS.

Raise hand or lamp up and down—Go ahead.

Swing hand or lamp across track—Stop.

Swing hand or lamp in circle to left—Back up.

Swing hand or lamp at full arm's length until engineer answers by three long whistles, Broke in two.

## SIGNALS CARRIED BY TRAINS.

Two green flags or lamps in front of engine—Another section following with same rights.

Two white flags or lights in front of engine —Special or wild train.

The lights on freight caboose are one cupola light, green front and red back, two lamps, one each side of car, each having front and sides green and back red.

Day signals are green flags.

The lights for passenger trains are the same except in place of a cupola light a large red bull's-eye sits on rear platform of last car.

## STATION OR FIXED SIGNALS.

Red flag or light—Danger, stop.

Green flag or light—Caution, slow.

White flag or light—Safe, clear track.

White flag or light at station—Stop for passengers.

Red flag or light at station—Stop for train orders.

## TORPEDO SIGNALS.

One torpedo—Stop.

Two torpedoes—Slow speed, careful, look out for signals.

Place one torpedo about ten telegraph poles from train or 1,600 feet, then go still further 1,600 feet and place two about 20 feet apart, leave the two torpedoes and go back to the single one, stay in that neighborhood until engineer blows four long whistles, then remove torpedo and run toward train; if passenger train is due wait, signal and ride in. Never place torpedoes near depot or wagon-road crossing.

Q. Name the different makes of switches.

A. The point or split switch, double split and old stub switches.

Q. What is a Y track and its use?

A. A Y track is two tracks from two different directions off main track, running together, forming a Y. It is used to turn engines, trains, etc.

Q. Explain the Block system.

A. It is a system of working railway traffic, according to which the line is divided

into sections of a mile or more, with a signal and telegraphic connection at end of each section. The principle of system being that no train is allowed to leave any one section until the next succeeding section is entirely clear, so that between two successive trains there is preserved definite intervals of time and space.

Q. What is meant by a semaphore?

A. A semaphore is a post that bears target signals.

Q. Explain semaphoric.

A. Semaphoric means targets operated by electricity.

Q. What is a railroad gauntlet?

A. A railroad gauntlet is the running together of parallel tracks of a double road passing in the space of one, going through a single tunnel or bridge without breaking the continuity of either rail.

Q. Suppose the target stood out at right angles with post and not in your favor, what would prevent you from going right along?

A. If by accident such a thing would happen, the engine would run off the end of rails, and that would qualify me for about 30 days' uncalled for vacation.

## MIXED QUESTIONS AND ANSWERS.

Q. What does a ton of soft coal contain?

A. It contains 2,000 cubic feet of gas, 1,500 pounds of coke, 20 gallons of ammonia water and 14 pounds coal tar.

Q. How would you find the area of any cylinder?

A. Multiply the diameter by diameter and answer by .7854.

Q. How many area square inches has a cylinder 16-inch diameter?

A. It has 201.06 square inches.

Q. State the different standard decimals used daily, namely, to find the circumference of any diameter's circle; also to find the cubic inch contents of a ball?

A. Standard number for circumference is 3.1416, and the standard number for cubic inches in a sphere use .5236.

Q. How do you understand a cubic? Explain by example, say a ball is 3¾ inches diameter.

A. A ball 3¾ inches diameter reads $3.75 \times 3.75 = 14.0625 \times 3.75 = 52.734375 \times .5236 = 27.6117187500 = 27\frac{61}{100}$ cubic inches in ball 3¾-inch diameter.

Q. Does it take more air to burn coke than coal?

A. Yes, it takes one-tnird more air for coke than coal.

Q. How many cubic feet of air does it take to consume one pound of coke?

A. It takes 330⅔. Example: 248 for coal; ⅓ of 248= 82⅔, added to 248= 330⅔.

Q. How are fractional parts of whole numbers made to read as whole numbers?

A. The fractional part of a whole number is made to read as a whole number by dividing the fractional part into 100 until nothing remains; answer will be fractional part in decimals, Example: ¾ of 100, 4÷100=.25×3=.75.

Q. How are they found, take $\frac{3}{16}$ of $1, for instance?

A. One=$1.00. Divide 16 into 100 until nothing remains. 16÷100=6.25×3=18.75, or 18¾c= $\frac{3}{16}$ of $1.00.

Q. How do you understand the horse power of a boiler?

A. The evaporation of 1 cubic foot of water per hour.

Q. How do you understand the horse power of a steam engine?

A. 33,000 lbs. raised 1 foot high in 1 minute.

Q. Give an explanation of a horse power?

A. First compare the rule with the actual power of a horse, and then apply it to the steam engine. The usual traveling gate of a horse, hitched to a light sulky is about 5 miles an hour, or 440 feet per minute. If a spring scale be attached to the singletree we may note the amount of power the horse is exerting. Assuming this to be 75 lbs. and the product of the speed per minute 440, multiply speed by lbs. or power exerted and the answer is 33,000 foot lbs., and represents a horse power.

Q. How is this applied to an engine?

A. In applying this to an engine, we first find the area of the cylinder, mutiply area by boiler pressure, and that answer by piston speed in feet per minute, and divide by 33,000. Answer will be nominal H. P.

Q. What deduction for cut off?

A. Deduct ⅓.

Q. How much for short cut-off?

A. Deduct ½.

Q. Why is this reduction made?

A. It is made for variation of pressure, friction, condensation, etc.

Q. Are you acquainted with any short rule by which a cylinder H. P. can be rated?

A. For small cylinders, from 2 to 12 inch

bore ; multiply diameter by itself and divide by 3. Answer is H. P. For larger cylinders from 16 to 20; divide by 4. Answer is H. P.

Q. Explain why engines with large cylinders as a rule have 3, 4 and 5 drivers on one side, also all of them connected?

A. The more drivers the more traction on the rail and the more load can be started. The reason for connecting all is more traction, and the heavy strain on the main pin divided up between other pins through the parallel rods.

Q. Is the piston-head in the middle of the cylinder's length when the crank pin is at either half stroke?

A. No.

Q. What is the cause of this?

A. It is caused by the main rod's length.

Q. Which travels the greater distance in one revolution, the cross head or the crank pin?

A. The crank pin,

Q. How much further does the crank pin travel than the crosshead in one-half revolution, also in one revolution?

A. The crank pin travels one-sixth further in a half revolution and one-third in one revolution.

Q. Does the crosshead stop in the guides at each dead point?

A. Yes.

Q. What is the crank pin doing while the crosshead is at dead point?

A. It is traveling one-sixth of the circumference.

Q. How many sixths are there in the travel of the crank pin?

A. There are six, one at each dead center divided into twelfths, and two for each full stroke of crosshead=six.

Q. What is the object in beveling engine and car wheels?

A. They are beveled to make up the difference as much as possible between the short and long rail in turning a curve, also to keep the train central between the rails.

Q. How does one know where to look for tensile strength, and what is tensile strength?

A. Generally the sheets are stamped, giving the exact T. S., and the meaning of the term is the amount of the hydraulic strain the sheet will test to per square inch in pulling asunder.

Q. Is it rulable to use full T. S. in working a boiler?

A. No; about one-sixth of it.

# RULES AND RECIPES.

To compute the speed of shafts, size of pulleys, etc. Example: To find the size of a driven pulley to give a shaft 160 revolutions driven by a 32-inch driver running 96 revolutions; simply multiply the driver, 32, by the speed it runs and divide by speed wanted. $96 \times 32 = 3072 \div 160 = 19$-inch pulley.

## TO TEST QUALITY OF IRON.

A soft, tough iron is known by fracture giving long silky fibres of a grayish hue, and the fibres covering and twisting together before breaking. Badly refined iron is known by its short blackish fibre. Brittle iron is indicated by coarse grain with brilliant crystalized break. This iron works easy, and welds easily when heated.

## TO TEST STEEL.

Good tool steel will fall to pieces at a white heat; at a bright red it will crumble under the hammer; at middle heat it may be drawn to a needle point.

To test hardening qualities: Draw under a low heat to a gradually tapered square point and plunge into cold water; if broken point will scratch glass the quality is good.

Recipe to Polish Boiler-Heads, Fire-Boxes, Smoke-Arches, Stacks, Etc.—Take an old sponge and common soap and make a suds; pour on some boiled oil and rub over boiler-heads, etc. This will leave a satin gloss polish instantly; do while warm.

Receipt to Cool Hot Pins, Journals, Etc.—Use small quantity of ammonia; work it through the oil cup; it will surprise you. Pulverized sulphur and plumbago mixed with machine oil is very good.

Calendar Calculations.—Rule to find on which day of the week any date will fall, in the future or past. Example: Set down the last two figures of the year, say 95. The ¼ of 95=23 (dropping the fractions), then add the date desired, say Feb. 3; then add the standard number following the month of February, which is 6; add all together and divide by 7, which are the seven days of the week; the answer remaining is 1; therefore Feb. 3, 1895, falls on the 1st day, Sunday.

| | |
|---|---|
| 95 year. | 1 remaining represents Sunday. |
| 23 ¼ year. | 2 " " Monday. |
| 3 days. | 3 " " Tuesday. |
| 6 Month No. | 4 " " Wedn'day. |
| — | 5 " " Thursday. |
| 7)127(18 | 6 " " Friday. |
| 126 | 7 or 0 " " Saturday. |
| — | |
| 1 Sunday. | |

Months with standard numbers: Jan. 3, Feb. 6, March 6, April 2, May 4, June 0, July 2, Aug. 5, Sept. 1, Oct. 3, Nov. 6, Dec. 1.

To test tenacity: Take a hardened piece and drive it into cast iron with hardened hammer; if poor it will crumble. Soft steel of good quality gives a curved line break and gray texture. Tool steel should be a dull silver color, equal and entirely free from sparkling qualities. Aquafortis, applied to the surface of steel, produces a black spot; and on iron the surface remains clean. The slightest vein of iron or steel can be detected by this method.

To remove dust from steel, brush the rusted steel with a paste composed of ½ oz. cyanide of potassium, ½ oz. castile soap, one oz. whiting and enough water to make a paste; then wash the steel in a solution of ½ oz. cyudide of potassium in two ozs. of water.

### TO CLEAN BRASS.

Take and mix one part common nitric acid, ½ part sulphuric acid, in a stove, having also a pail of fresh water and a box of sawdust. Dip articles into acid, and then soak in water, and finally rub them in sawdust, and the brass will be bright.

If the brass is greasy, first dip into a strong solution of potash and soda in water; then rinse, so the grease may be removed, leaving the acid free to act upon the brass.

To keep machinery from rusting: Take one oz. of camphor and dissolve it in one pound of melted lard; take off the scum, and mix in as much fine black as will give it iron color. Clean the machinery and smear it with the mixture. After 24 hours, rub clean with a soft linen cloth. It will keep clean for months under ordinary circumstances.

### BOILER COVERING.

Take 16 pounds of rye flour, 32 pounds flax seed meal and 15 gallons of water, boil for one hour; then add three pails of dry clay, three pails of sifted ashes and seven pounds of hair. The above proportions will make about one barrel. For outside finishing, use half the amount of hair.

### CEMENT.

Cement to fasten iron to stone; when made, use at once. Take ten parts of fine iron filings; thirty parts of plaster of paris and ½ part of salammoniac, mix with weak vinegar to a fluid paste, and apply at once as it sets very quickly.

To avoid tearing manhole gaskets, put a little white lead on the surface of the gasket, which rests on the manhole plate, and chalk the outer surface of the gasket heavily, as

also the part of the manhole frame with which it comes in contact.

### STEAM HEATING.

Allow one square foot of heating surface in a boiler for every 200 feet of space in a church; in a dwelling allow one square foot to every 50 cubic feet. The radiators should have one square foot of superficial area to every six square feet of glass in windows, and one square foot for every 80 feet to be heated.

One horse power in a boiler is generally sufficient for 40,000 cubic feet of space for a temperature of 70 degrees Fahr.

### CAPACITY OF TANKS.

To ascertain the capacity of a tank, multiply the square of the diameter by 5.873 and the result will give gallons for one foot in depth.

Example: Tank 10 feet in diameter $10 \times 10 = 100 \times 5.873 = 587$ gallons. To find capacity of square tank in gallons multiply length by breadth, then by height in inches = cubic contents and divide by 231 (number of cubic inches in a standard gallon).

Safe working pressure of a boiler: Multiply twice the thickness of the shell by the tensile strength (found stamped on boiler sheet) and divide by the diameter of the shell in inches.

Rule to determine weight on safety valve lever: Multiply area of valve by pressure of steam per square inch wanted to blow off at; from this answer subtract the weight of lever, valve, stem and pin; then multiply the remainder by the distance from the valve to the fulcrum; divide by the distance from fulcrum to where weight is to be placed; the answer will be the required weight.

### TO CUT A GLASS GAUGE TUBE.

If tube is too long, take a three-cornered file and wet it; hold the tube in one hand with the thumb and fore-finger at the place where you wish to cut it; saw it quickly and lightly two or three times with the edge of the file. Now take the tube in both hands, both thumbs being at the opposite side to the mark and about one inch apart, then try to bend the glass, using your thumb as fulcrum. It will break at the mark every time.

### LIME WATER.

To make a lime water for scalds and burns: Slack a small piece of lime; as soon as the water is clear, mix it with linseed oil, enough to make a cream-like substance. This will exclude the air from the burnt parts and allay inflammation almost instantly.

## CALCULATING INTEREST.

### SHORT RULES.

If at six per cent, multiply the dollars by the number of days and divide by six, and cut off one figure on the right. Example: what is the interest on \$73.25 from April 12th to July 15th, which is 94 days? $73.25 \times 94 = 6885 \div 6 =$ \$1.15. If at seven per cent, after following above rule, add 1-6 thus, $1.15 + 19 =$ \$1.34. If at five per cent, after following the rule, deduct 1-6 thus, $1.15 - 19 = 96$ cents.

## BRICK WORK

### FOR BOILERS AND ENGINE BEDS.

The size of a common brick is $2.66 \times 3.85 \times 7.70$; the size of a fire brick is $2.66 \times 4\frac{1}{2} \times 8\frac{7}{8}$.

Weight of brick work is 112 pounds per cubic foot; weight of stone work is from 116 to 144 pounds per cubic foot, 21 bricks equal one cubic foot, $4\frac{1}{2}$ bricks laid flat equal one superficial foot. In setting boilers use only the best hard brick for walls, and the best fire brick for lining furnace surfaces. If the boiler has side lugs to bear its weight, the forward lugs should rest directly on lug plates placed on the walls, and the rear lugs on expansion rollers placed crosswise on the wall plates under the centre of lugs. Keep the brick work away from the lugs

over expansion rollers, you will not be bothered with cracked walls.

The bridge walls should be faced and capped with fire brick, and built up within six inches of the shell, sloped toward the back, circular with the boiler. The flue at back of boiler should be formed by an arch spring from side-walls, or by wrought iron plates covered with two thicknesses of brick, these plates to be supported by T iron cross-beams set flush on under side and below the manhole of boiler or below the water line.

To know the number of bricks it will take to set a boiler in 12 inch walls: multiply length of wall by height in feet, and multiply by 21 (the number of bricks in a cubic foot.) Example: wall 15 feet long, 8 feet high, opposite wall the same, rear wall $5 \times 8$, bridge wall 5 feet long, 2 feet wide, average 3 feet high; $15 \times 8 = 120$ two walls $= 240$ $5 \times 8 = 40$ $5 \times 2 = 10 \times 3 = 30$ $240 + 40 + 30 = 310$ cubic feet; which multiplied by $21 = 6510$ bricks. This will take $6\frac{1}{2}$ barrels of lime and $6\frac{1}{2}$ barrels of sand as mortar. Allowance is to be made for the covering of top of boiler paving ashpit and for fire brick in building front connection. Use only fire clay in furnace. Lime mortar mixed with very little cement is good for pits. Lime mortar stands heat better than cement.

## ENGINE FOUNDATION.

The foundation of an engine should be built one foot lower than the fly wheel and one width of a brick wider all around the bed plate of engine and 14 inches wider at the base all around. Out bearing pillow block should be built the same in proportion and run a stay or brace from engine bed to pillow block brick work.

To ascertain the number of bricks required, find the average width and length, then multiply length by width by full height, and then by 21, which gives number of bricks. Use hard burnt brick or bats for filling, or fill with rubble or concrete made of three barrels of stone rubbish, two barrels of sand, and one barrel of cement, mix and wet down. The foundation should be laid in cement and sand mixed, one part sand and two parts cement. To every 1000 bricks use two barrels cement and one barrel of sand.

To ascertain the expansion of wrought iron pipes. Multiply the length of pipe in inches by the number of degrees to which it is heated, and divide by $1\frac{150}{1000}$, which gives the expansion in inches. Cast iron pipe expands $1\frac{162}{1000}$ of its length for each degree Fahr. it is subjected to under ordinary circumstances. Wrought iron pipe $1\frac{150}{1000}$. A two inch pipe when heated to

338 degrees Fahr. or 100 pounds pressure, exerts an expansion force of twenty-five tons.

The melting, boiling, and freezing points of various substances, and metals in alphabetic form.

### MELTING.

| | | |
|---|---|---|
| Antimony melts at | 951 | Deg. |
| Bismuth melts at | 476 | " |
| Brass melts at | 1900 | " |
| Cast Iron melts at | 3479 | " |
| Copper melts at | 2548 | " |
| Glass melts at | 2377 | " |
| Gold melts at | 2590 | " |
| Ice melts at | 32 | " |
| Lead melts at | 594 | " |
| Platinum melts at | 3080 | " |
| Silver melts at | 1250 | " |
| Steel melts at | 2500 | " |
| Tin melts at | 421 | " |
| Zinc melts at | 740 | " |

### BOILING.

| | | |
|---|---|---|
| Ether boils at | 100. | Deg. |
| Fresh water boils at | 212. | " |
| Linseed Oil boils at | 340. | " |
| Mercury boils at | 662. | " |
| Naptha boils at | 186. | " |
| Oil of turpentine boils at | 304. | " |
| Sea water boils at | 213.½ | " |
| Sweet Oil boils at | 412. | " |

### FREEZING.

| | | | |
|---|---|---|---|
| Ether freezes at | 47. | Belew | Zero. |
| Mercury freezes at | 40. | " | " |
| Sea Water freezes at | 28. | " | " |
| Sweet Water freezes at | 32. | Above | " |
| Wine freezes at | 20. | " | " |

Alcohol has no record of ever having been frozen. The claim is that alcohol has been exposed to one hundred and twenty degrees below zero without freezing.

## HOW SOUND TRAVELS.

In dry air at 82 degrees 1141 feet per second, or about 775 miles per hour; in water, 4,900 feet per second; in iron, 17,500 feet; in copper, 10,378 feet; and in wood from 12,000 to 16,000 feet per second. In water a bell heard at 45,000 feet could be heard in the air out of the water but 656 feet. In a balloon the barking of a dog on the earth can be heard at an elevation of 22,000 feet or four miles.

Divers on the wreck of the Huzzar frigate, one hundred feet under water at Hell gate, near New York, heard the paddle wheels of distant steamers hours before they hove in sight. The report of a rifle on a still day may be heard at 5,300 yards; a military band at 5,200 yards. The fire of the English on landing in Egypt was distinctly heard 130 miles. Dr. Jamieson said he heard, during a calm day, every word of a sermon at a distance of two miles.

The first steamboat plied the Hudson in 1807.

The first saw-maker's anvil was brought to America in 1819.

The first use of a locomotive in this country was in 1820.

The first use of a stationary engine was in 1625.

The first use of kerosene for lighting purposes was in 1826.

The first horse railroad was built in 1826 and '27.
The first lucifer match was made in 1829.
The first iron steamship was built in 1830.
The first air pump was used in 1650.
The first newspaper advertisment appeared in 1652.
The first copper cent was coined in New Haven in 1687.

How to destroy the effects of acid on clothes: dampen as soon as possible with spirits of ammonia and the effect will be destroyed immediately.

A good cement to stop holes in castings is eight parts of sifted cast iron turnings, two parts of powdered salammoniac and one part sulpher made into thick paste with water and mixed fresh for use is very fine.

To make a fine oil for watches or fine machinery. Put thin strips of lead in a large mouth bottle and pour over pure olive oil, and leave it stand in the sun about three weeks, then pour off the clear oil, and you will have an oil which which will neither corrode or gum.

A good varnish for boiler fronts, smoke stacks and steam pipes is good asphaltum, dissolved in oil of turpentine.

Cement for joints for steam exhaust or waste pipes that will set under water: Paris white ground, four pounds; litharge ground, ten pounds, yellow ochre, fine, half pound; hemp,

one-half oz., cut short and mix all together with linseed oil to a stiff putty.

### TEMPERING.

Tempering of fine springs, after bringing to the proper shape desired: heat slowly to a cherry red and plunge in black oil; after the spring is cool hold it over the fire and burn the oil off; dip the spring in the oil three times in this manneer and burn off each time; after the last burning plunge into water and cool preparatory to polishing.

To temper engraver's diamond point tools, heat to nearly white heat and stick the tool into sealing wax until cool, then dip point into oil of turpentine.

To temper common flat, cape or side chisels and flat drills. Shape them ready for the grindstone, then heat the points about two or three inches back to cherry red and plunge point into luke warm water, leaving the black part warm to drive out the temper to the point, polish point with sand and watch results. When proper temper is attained, plunge whole tool into cold water.

Colors: For chipping or drilling cast iron the tools should be dark straw turning to blue. Color for steel and iron should be pretty near blue, and softer than for cast iron.

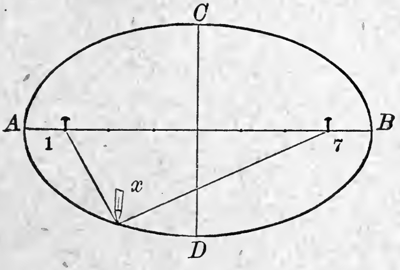
To join a band saw when broken: Bevel each end the length of two blades, fasten saw in brazing clamp, wet the joint with solder water made of borax rubbed on slate with water, place piece of silver solder in joint full size and squeeze together with red hot tongs. When solder fuses throw water on tongs and cool while holding the joint. Hammer saw if necessary and draw file down to proper thickness.

To renew worn files: thorougly cleanse them from grease or oil with alkali, then dip them in a solution made with one part nitric acid, three parts sulphuric acid, seven parts water by weight; time, five seconds to five minutes, according to fineness of cut. Wash in hot water, dip in lime water, dry and oil them.

To inscribe metal: cover the part with melted beeswax; when cold, write what you desire plainly in the wax clean to the metal with scriber, then apply a mixture of ½ oz. nitric acid, 1 oz. muriatic acid, with a feather, carefully fill each letter; let it remain from one to ten minutes according to appearance desired, then throw on water to stop the process of cutting, heat wax to remove it, and you have your name.

To draw an ellipse, such as man-holes and hand-holes. This can be done by means of a string, pencil and two pins. First lay two lines

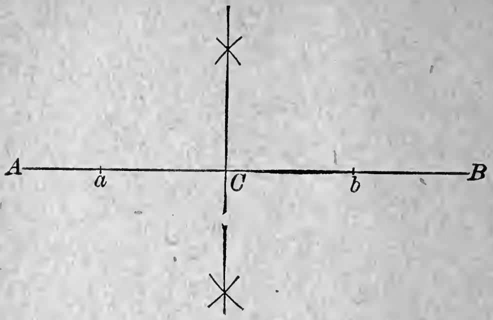
each crossing the other in the middle; these lines to represent the length and breadth of the figure mark the ends of lines A, B, C, D, and then divide the major axis A, B into eight parts,




and fix two pins at the divisions, one and seven, as per cut, now fasten one end of a string to 7, and stick a temporary pin at D, pass the string around it and make the string fast to the pin at 1, then remove the temporary pin, put the point of a pencil, as x, inside the loop and describe $\frac{1}{2}$ the ellipse, then shift the position of the string to the other side of the line A, B, and describe the other half.

To make a square or erect a perpendicular line from any point in a straight line. Let the point C on the straight line A, B, be the one at which it is required to erect a perpendicular.

Now, to do this, set one leg of a pair of dividers at C, and then open them to any convenient dis-




tance, say four or twenty inches, C, a, b, put point of dividers at small a, and cross about where the perpendicular should stand, then strike another from where b is, and where the two arcs cross join with C, and the perpendicular line will be the square with parallel line (45 degrees.)

**Rule to find Circumferences:** Multiply the diameter by 3.1416. To find the diameter: Divide the circumference by 3.1416, also find the diameter by multiplying the circumference by .31831.

| Size. | Cir. | Size. | Cir. | Size. | Cir. |
|---|---|---|---|---|---|
| $\frac{1}{8}$ | .3926 | 10 | 31.41 | 30 | 94.24 |
| $\frac{1}{4}$ | .7854 | $\frac{1}{2}$ | 32.98 | 31 | 97.38 |
| $\frac{3}{8}$ | 1.178 | 11 | 34.55 | 32 | 100.5 |
| $\frac{1}{2}$ | 1.570 | $\frac{1}{2}$ | 36.12 | 33 | 103.6 |
| $\frac{5}{8}$ | 1.963 | 12 | 37.69 | 34 | 106.8 |
| $\frac{3}{4}$ | 2.356 | $\frac{1}{2}$ | 39.27 | 35 | 109.9 |
| $\frac{7}{8}$ | 2.748 | 13 | 40.84 | 36 | 113.0 |
| 1 | 3.141 | $\frac{1}{2}$ | 42.41 | 37 | 116.2 |
| $\frac{1}{8}$ | 3.534 | 14 | 43.98 | 38 | 119.3 |
| $\frac{1}{4}$ | 3.927 | $\frac{1}{2}$ | 45.55 | 39 | 122.5 |
| $\frac{3}{8}$ | 4.319 | 15 | 47.12 | 40 | 125.6 |
| $\frac{1}{2}$ | 4.712 | $\frac{1}{2}$ | 48.69 | 41 | 128.8 |
| $\frac{5}{8}$ | 5.105 | 16 | 50.26 | 42 | 131.9 |
| $\frac{3}{4}$ | 5.497 | $\frac{1}{2}$ | 51.83 | 43 | 135.0 |
| $\frac{7}{8}$ | 5.890 | 17 | 53.40 | 44 | 138.2 |
| 2 | 6.283 | $\frac{1}{2}$ | 54.97 | 45 | 141.3 |
| $\frac{1}{4}$ | 7.068 | 18 | 56.54 | 46 | 144.5 |
| $\frac{1}{2}$ | 7.854 | $\frac{1}{2}$ | 58.11 | 47 | 147.6 |
| $\frac{3}{4}$ | 8.639 | 19 | 59.69 | 48 | 150.7 |
| 3 | 9.424 | $\frac{1}{2}$ | 61.26 | 49 | 153.9 |
| $\frac{1}{4}$ | 10.21 | 20 | 62.83 | 50 | 157.0 |
| $\frac{1}{2}$ | 10.99 | $\frac{1}{2}$ | 64.40 | 51 | 160.2 |
| $\frac{3}{4}$ | 11.78 | 21 | 65.97 | 52 | 165.3 |
| 4 | 12.56 | $\frac{1}{2}$ | 67.54 | 53 | 166.5 |
| $\frac{1}{2}$ | 14.13 | 22 | 69.11 | 54 | 169.9 |
| 5 | 15.70 | $\frac{1}{2}$ | 70.68 | 55 | 172.7 |
| $\frac{1}{2}$ | 17.27 | 23 | 72.25 | 56 | 175.9 |
| 6 | 18.84 | $\frac{1}{2}$ | 73.82 | 57 | 179.0 |
| $\frac{1}{2}$ | 20.42 | 24 | 75.39 | 58 | 182.2 |
| 7 | 21.99 | $\frac{1}{2}$ | 76.96 | 59 | 185.3 |
| $\frac{1}{2}$ | 23.56 | 25 | 78.54 | 60 | 188.4 |
| 8 | 25.13 | 26 | 81.68 | 61 | 191.6 |
| $\frac{1}{2}$ | 26.70 | 27 | 84.82 | 62 | 194.7 |
| 9 | 28.27 | 28 | 87.96 | 63 | 197.9 |
| $\frac{1}{2}$ | 28.84 | 29 | 91.10 | 64 | 201.0 |

# WEIGHTS AND MEASURES

## TROY WEIGHT.

| | |
|---|---|
| 24 grains | 1 pennyweight (dwt.) |
| 20 pennyweights | 1 ounce (oz.) 480 grains. |
| 12 ounces | 1 pound (lb.) 6760 grains. |
| 20 grains | 1 scruple. |
| 3 scruples | 1 dram 60 grains. |
| 8 drams | 1 ounce 480 grains. |
| 12 ounces | 1 pound 5760 grains (gr.) |

## AVOIRDUPOIS WEIGHT.

| | |
|---|---|
| 27.34375 grains | 1 dram. |
| 16 drams | 1 ounce 437½ grains. |
| 16 ounces | 1 pound 7000 grains. |
| 28 pounds | 1 quarter (qr.) |
| 4 quarters | 1 hundredweight (cwt.) 112 pounds. |
| 20 hundredweight | 1 ton (T) 2240 pounds. |

## U. S. LIQUID MEASURE.

| | |
|---|---|
| 4 gills | 1 pint (pt) 28.875 cubic inches. |
| 2 pints | 1 quart (qt.) 57.750 cubic inches |
| 4 quarts | 1 gallon (gal.) 231 cubic inches |
| 63 gallons | 1 hogshead (hhd.) |
| 2 hogsheads | 1 pipe (p.) |
| 2 pipes | 1 ton. |

## U. S. DRY MEASURE.

| | |
|---|---|
| 2 pints | 1 quart (qt.) 67.2006 cubic inches. |
| 4 quarts | 1 gallon (gal.) 8 pts. 268.8025 cubic inches. |
| 2 gallons | 1 peck (pk.) 16 pts. 8 qts. 537.605 cubic inches. |
| 4 pecks | 1 bushel (bush) 64 pts. 32 qts. 8 gals. 2150.42 cubic inches. |

## LONG MEASURE.

| | |
|---|---|
| 12 inches | 1 foot (ft.) |
| 3 feet | 1 yard (yd.) 36 inches. |
| 5½ yards | 1 rod (rd.) 16½ feet. |
| 40 rods | 1 furlong (fur.) 220 yards 660 feet. |
| 8 furlongs | 1 mile (m) 320 rods 1760 yards 5280 feet. |
| 3 miles | 1 league (l.) 960 rods 5280 yards 15840 feet. |

# PROPERTIES OF SATURATED STEAM.

| Pressure. | | Temperature in Fahrenheit Degrees. | Volume. | | Latent Heat in Fahrenheit Degrees. | Total heat required to saturate 1 lb. of Steam from water at 32 deg. under constant pressure. In heat units. |
|---|---|---|---|---|---|---|
| By Steam Guage | Total | | Compared with water. | Cubic feet of Steam from 1 lb. of water. | | |
| 0 | 15 | 212.0 | 1642 | 26.36 | 965.2 | 1146.1 |
| 5 | 20 | 228.0 | 1229 | 19.72 | 952.8 | 1150.9 |
| 10 | 25 | 240.1 | 996 | 15.99 | 945.3 | 1154.6 |
| 15 | 30 | 250.4 | 838 | 13.46 | 937.9 | 1157.8 |
| 20 | 35 | 259.3 | 726 | 11.65 | 931.6 | 1160.5 |
| 25 | 40 | 267.3 | 640 | 10.27 | 926.0 | 1162.9 |
| 30 | 45 | 274.4 | 572 | 9.18 | 920.9 | 1165.1 |
| 35 | 50 | 281.0 | 518 | 8.31 | 916.3 | 1167.1 |
| 40 | 55 | 287.1 | 474 | 7.61 | 912.0 | 1169.0 |
| 45 | 60 | 292.7 | 437 | 7.01 | 908.0 | 1170.7 |
| 50 | 65 | 298.0 | 405 | 6.49 | 904.2 | 1172.3 |
| 55 | 70 | 302.9 | 378 | 6.07 | 900.8 | 1173.8 |
| 60 | 75 | 307.5 | 353 | 5.68 | 897.5 | 1175.2 |
| 65 | 80 | 312.0 | 333 | 5.35 | 894.3 | 1176.5 |
| 70 | 85 | 316.1 | 314 | 5.05 | 891.4 | 1177.9 |
| 75 | 90 | 320.2 | 298 | 4.79 | 888.5 | 1179.1 |
| 80 | 95 | 324.1 | 283 | 1.55 | 885.8 | 1180.3 |
| 85 | 100 | 327.9 | 270 | 4.33 | 883.1 | 1181.4 |
| 90 | 105 | 331.3 | 257 | 4.14 | 880.7 | 1182.4 |
| 95 | 110 | 334.6 | 247 | 3.97 | 878.3 | 1183.5 |
| 100 | 115 | 338.0 | 237 | 3.80 | 875.9 | 1184.5 |
| 110 | 125 | 344.2 | 219 | 3.51 | 871.5 | 1186.4 |
| 120 | 135 | 350.1 | 203 | 3.27 | 867.4 | 1188.2 |
| 130 | 145 | 355.6 | 190 | 3.06 | 863.5 | 1189.9 |
| 140 | 155 | 361.0 | 179 | 2.87 | 859.7 | 1191.5 |
| 150 | 165 | 366.0 | 169 | 2.71 | 856.2 | 1192.9 |
| 160 | 175 | 370.8 | 159 | 2.56 | 852.9 | 1194.4 |
| 170 | 185 | 375.3 | 151 | 2.43 | 849.6 | 1195.8 |
| 180 | 195 | 379.7 | 144 | 2.31 | 846.5 | 1197.2 |

This table gives the value of all properties of saturated steam required in calculations connected with steam boilers.

# AREA OF CIRCLES.

To find the area of a circle, square the diameter and multiply by .7854.

| SIZE. | AREA. | SIZE. | AREA. | SIZE. | AREA. | SIZE. | AREA. |
|---|---|---|---|---|---|---|---|
| ⅛ | 0.0123 | 10 | 78.54 | 30 | 706.86 | 65 | 3318.3 |
| ¼ | 0.0491 | ½ | 86.59 | 31 | 754.75 | 66 | 3421.2 |
| ⅜ | 0.1104 | 11 | 95.03 | 32 | 804.24 | 67 | 3525.6 |
| ½ | 0.1963 | ½ | 103.86 | 33 | 855.30 | 68 | 3631.6 |
| ⅝ | 0.3067 | 12 | 113.09 | 34 | 907.92 | 69 | 3739.2 |
| ¾ | 0.4417 | ½ | 122.71 | 35 | 962.11 | 70 | 3848.4 |
| ⅞ | 0.6013 | 13 | 132.73 | 36 | 1017.8 | 71 | 3959.2 |
| 1 | 0.7854 | ½ | 143.13 | 37 | 1075.2 | 72 | 4071.5 |
| ⅛ | 0.9940 | 14 | 153.93 | 38 | 1134.1 | 73 | 4185.3 |
| ¼ | 1.227 | ½ | 165.13 | 39 | 1194.5 | 74 | 4300.8 |
| ⅜ | 1.484 | 15 | 186.71 | 40 | 1256.6 | 75 | 4417.8 |
| ½ | 1.767 | ½ | 188.69 | 41 | 1320.2 | 76 | 4536.4 |
| ⅝ | 2.073 | 16 | 201.06 | 42 | 1385.4 | 77 | 4656.0 |
| ¾ | 2.405 | ½ | 213·82 | 43 | 1452.2 | 78 | 4778.3 |
| ⅞ | 2.761 | 17 | 226.98 | 44 | 1520.5 | 79 | 4901.6 |
| 2 | 3.141 | ½ | 240.52 | 45 | 1590.4 | 80 | 5026.5 |
| ¼ | 3.976 | 18 | 254.46 | 46 | 1661.9 | 81 | 5153.0 |
| ½ | 4.908 | ½ | 268.80 | 47 | 1734·9 | 82 | 5281.0 |
| ¾ | 5.939 | 19 | 283.52 | 48 | 1809.5 | 83 | 5410.6 |
| 3 | 7.068 | ½ | 298.64 | 49 | 1885.7 | 84 | 5541.7 |
| ¼ | 8.295 | 20 | 314.16 | 50 | 1963.5 | 85 | 5674.5 |
| ½ | 9.621 | ½ | 330.06 | 51 | 2042.8 | 86 | 5808.8 |
| ¾ | 11.044 | 21 | 346.36 | 52 | 2123.7 | 87 | 5944.6 |
| 4 | 12.566 | ½ | 363.05 | 53 | 2206.1 | 88 | 6082.1 |
| ½ | 15.904 | 22 | 380.13 | 54 | 2290.2 | 89 | 6221.1 |
| 5 | 19.635 | ½ | 397.60 | 55 | 2375.8 | 90 | 6361.7 |
| ½ | 23.758 | 23 | 415.47 | 56 | 2463.0 | 91 | 6503.8 |
| 6 | 28.274 | ½ | 433.73 | 57 | 2551.7 | 92 | 6647.6 |
| ½ | 33.183 | 24 | 452.39 | 58 | 2642.0 | 93 | 6792.9 |
| 7 | 38.484 | ½ | 471.43 | 59 | 2733.9 | 94 | 6939.7 |
| ½ | 44.178 | 25 | 490.87 | 60 | 2827.4 | 95 | 7088.2 |
| 8 | 50.265 | 26 | 530.93 | 61 | 2922.4 | 96 | 7238.2 |
| ½ | 56.745 | 27 | 572.55 | 62 | 3019.0 | 97 | 7389.8 |
| 9 | 63.617 | 28 | 615.75 | 63 | 3117.2 | 98 | 7542.9 |
| ½ | 70.882 | 29 | 660.52 | 64 | 3216.9 | 99 | 7697.7 |

## MISCELLANEOUS.

Paints, Calcimining, Stains, Colors, etc.—Soak one pound of white calcimine glue in enough water to cover it, over night; then dissolve in boiling water, add twenty pounds of whiting diluted with water until the mixture is of the consistency of cream. To this any tint can be given that is desired.

### TINTS.

Lilac—Add to the calcimine two parts of Prussian blue and one of vermillion, stirring thoroughly and taking care to avoid too high a color.

Gray—Raw umber with a small amount of lampblack.

Rose—Three parts of vermillion and one of red lead added in very small quantities until a delicate shade is produced.

Lavender—Mix a light blue and tint it slightly with vermillion.

Straw—Chrome yellow with a touch of Spanish brown.

Buff—Two parts spruce or Indian yellow and one part burnt sienna.

### WOOD STAINS.

Mahogony—Boil one oz. extract of logwood and two ozs. fustic in one quart of water;

brush the wood with this, then go over with a weak solution of potash.

Black—Dissolve one oz. extract of logwood in one quart of water; wash the wood with the solution. When dry, wash in vinegar in which rusty iron has been steeped for several days.

Golden Yellow—Put ¼ oz. powdered turmeric in five fluid ounces alcohol in a closely stoppered bottle, let stand a week in a warm place, shake it occasionally, then strain off clear.

Black Walnut—Scald ¼ pound burnt umber in one pint of vinegar; strain, and apply with a sponge, when dry rub hard; repeat the staining until sufficiently dark.

Walnut No. 2—Asphaltum thinned with turpentine produces a splendid imitation of the natural wood. It must be varnished after staining.

Walnut No. 3—Very thin sized shellac, one gallon; dry umber, burnt, one lb.; rose pink, ½ lb.; Vandyke brown, burnt, ½ lb.; mix, let stand a day, then stir up and apply with a sponge.

Orange—Put one ounce turmeric and a drachm of gum tragacanth in a pint of alcohol; shake well, and after standing four days, strain.

Red—Two ozs. potash and two ozs. Brazil wood in one quart of water; let stand in a warm

place a few days, stirring occasionally; heat to a boiling point, and apply. Double the quantity of potash (four ozs.) will give a brilliant rose color to the wood.

Cherry, on white wood or pine—Alcohol, one quart; ground turmeric, three ozs.; raw gamboge, 1½ ozs. Mix well, strain through fine muslin, apply two coats with a sponge, rub down well, and varnish.

Antique Oak—Walnut oil, obtained of the druggist, if mixed with the filling applied to red oak or white oak, it will produce the antique effect so much sought after and used on furniture and interior finished houses.

Quantity of paints, material required for priming, if tinted white lead is used, it will take twenty pounds of lead and five quarts of raw linseed oil.

For second coat, twenty pounds of lead and one gallon of oil. If three-coat work is intended, the amount of material required for priming and completing the work will average fifty pounds of lead and 2½ gallons of oil.

To measure painting in square or 100 feet, allow five lbs. of lead one quart of oil. It takes already mixed paints one gallon per coat for each 25 square yards.

All should learn how to mix and apply

paint. Often at your leisure you can apply your time profitably about your home or engine room to beautify the looks and value of the property.

When to Paint.—Paint in the fall, winter or early spring, as paint at that season dries slowly and makes a hard, glossy surface.

Brushes.—The character of work done will determine the kind of brush to use. One or two flat and three round brushes of various sizes will be sufficient; wire bound ones are the most durable. After use, the brushes should be thoroughly cleaned with turpentine and covered with tallow.

House Painting.—If the house be new, the knots should be covered with shellac to prevent the rosin from running and discolor the paint. The first coat is white lead and raw linseed oil; boiled oil and turpentine are used in after coats. For inside finish, equal parts of boiled oil and turpentine are used for the second coat, and nearly all turpentine for last coat.

The color desired should be in the last coat, the first being pure white lead.

Harmony of Colors.—Care should be taken not to use the colors that would give an unpleasing effect to the work.

Common White Paints.—Mix white lead

with linseed oil, bringing to the consistercy of paste; then add one part turpentine to three parts oil to right consistency.

Milk Paints.—Mix water lime with skimmed milk to a proper degree of consistency, to be applied with a brush. It will adhere to anything where oil paint has not been used or applied, and is as durable as oil paint. Colors dissolved in whiskey may be added if desired.

Compounding Colors.—Any number of shades of colors may be made by mixing other colois. The following shows how to produce some of the most popular shades:

Flesh color is made with white lead, lake and vermillion.

Cream color is chrome yellow, venetian red, white lead and red lead in oil.

Buff is French yellow, chrome yellow and white lead with tinge of venetian red mixed in oil.

Violet—Vermillion, blue black and little white.

Dark Red—Mix Venetian red in boiled oil, little red lead and litharge.

Orange—Red lead and French yellow linseed oil.

Black and Green.—Durable and cheap black paint is made by grinding powdered charcoal

in linseed oil, with a little litharge as a drier. Add yellow ochre to this and an excellent green is obtained which will not fade.

Cheap Paint for Out Buildings.—Lime, one bushel, and water to make a whitewash; mineral paint, fifty lbs.; road dust, fifty lbs.; add oil till it makes a paste, and thin with sweet milk.

Cheap Oak Varnish.—Boiled oil, two quarts; litharge, ½ lb.; shellac, ¾ lb.; gum, one oz.; boil till dissolved, then cool, and add two quarts of turpentine.

Good Liniment for Man or Beast.—Take ½ oz. turpentine, ½ oz. tincture of aqua laudanum, ½ oz. oil of sassafras, ½ oz. hemlock oil, two ozs. tincture myrrh, one oz. oil of origanum, ¼ oz. oil of wintergreen, one oz. chloroform, one oz. camphor gum. Mix and apply externally to parts affected. Highly recommended for rheumatism, sprains, bruises, swellings, etc., on man or beast. Apply twice a day with naked hand; rub thoroughly.

Indelible Ink.—Aniline black, one drop; concentrated hydro chloric acid, sixty drops; alcohol, ½ oz. Mix and add 1½ oz. gum arabic dissolved in six ozs. soft water.

Liquid Glue.—Dissolve good hard glue in nitric ether. The ether will only take up a

certain amount of the glue, so it will not thicken. If small bits of India rubber be added it will resist dampness.

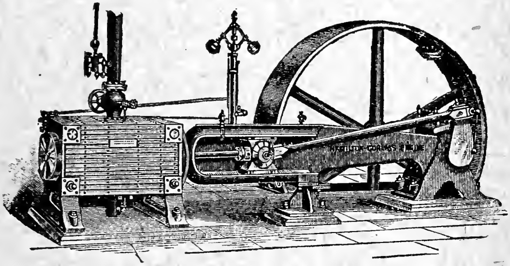
THE USE OF EXHAUST STEAM FOR HEATING PURPOSES.—Steam users and engineers have long been interested in the advantages to be derived from the utilization of the exhaust steam from engines or steam pumps, instead of wasting it into the air. By using it as a source of heat to warm manufactories, buildings, etc., and for certain manufacturing processes requiring heat, a large percentage of the thermal value of the fuel consumed in boiler furnaces, which is ordinarily lost, is utilized, thus insuring economy in fuel. The exhaust steam as it comes from the engine at a little more than 212 degrees Fahr. can be, and is used, to some advantage and economy under certain conditions, but experience has shown that owing to its low temperature, moist condition and comparative slow velocity, it is less efficient for the purpose of conveying and radiating heat than steam of a higher temperature; that is liable to sudden and rapid condensation, and that it is difficult to obtain a free circulation for heating purposes which eventuates in back pressure on the engine, neutralizing its value by reason of the extra fuel required to enable

the engine to carry the extra load. The limit of fair economy in use of exhaust steam is two to three pounds back pressure; beyond this, use live steam to assist in circulation. A reheater through which the gases pass after leaving the furnace is a valuable improvement in exhaust steam heating; about one hundred degrees of heat is imparted to exhaust steam without interruption of draught or extra expenditure of fuel by means of the heat that would otherwise go to water. Chimney gases have a temperature of 400 to 600 degrees, while that of exhaust steam is about 212 degrees. The economy of this method is therefore evident

Heating Feed Water.—This is a very important department of the steam plant; the feed water supplied to steam boilers has to be heated from the normal temperature to that of steam before evaporation can take place, and this is generally done at the expense of the fuel which should be utilized in making steam. The pressure at 75 pounds is 320 degrees heat; taking 60 degrees as the average temperature of feed we have 260 units of heat per pound, which, as it takes 1151 units to evaporate a pound from 60 degrees, represents a loss of 22½ per cent of fuel. All of this heat, there-

fore, which can be imparted to the feed water is just so much saved, not only in cost of fuel, but in capacity of boiler. All heat imparted to feed water by injection and "live steam heaters" is taken from the fuel and does not represent any saving.

There are two sources of waste heat available for this purpose—exhaust steam partially used and chimney gases.



CORLISS ENGINE.

The valve gear of Corliss engines are easily set, when one knows and understands a common slide-valve, as the four valves of a Corliss engine represent the two steam and the two exhaust edges of a common slide-valve.

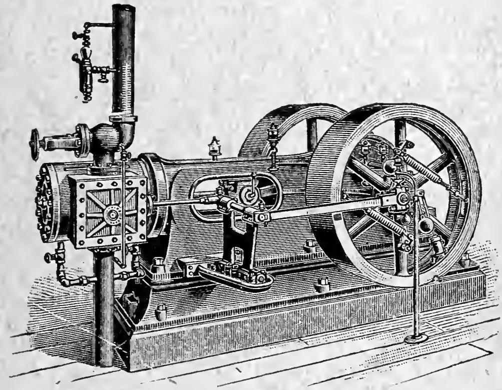
To set the Corliss valve, take off the back valve and exhaust valve chest heads. There will be found marks to set by. See that the wrist plate and four valves are connected and centrally covering their respective ports, that the crank-pin is at dead centre, and the eccen-

tric (heavy side) perpendicular. Move the eccentric the direction the engine is to be run and show by the valve chest marks and the edge of valve 1-16 lead (or opening) tighten the eccentric, and move the crank-pin to the other dead centre, and notice if the other steam valve has the same lead; if equal, the steam valves are O. K.; if not, make the adjust of ½ it is out, by the connections between the wrist plate and valve. Give the exhaust valves double the lead of steam valves.

To adjust the governor rods or tripping cams, move the wrist plate to one extreme of its travel, adjust the rod connecting with cut-off cam on opposite steam valve, so cam will clear the steel 1-32 of an inch; then do the opposite valve the same. To equalize and test their correctness, hook in the engine with eccentric reach-rod and block up the governor about 1¼ inches, or about the average position the governor will be in when running; then have some one move the fly-wheel in the running direction, and take notice how far the crosshead (from dead centre) has traveled when the valve unhooks; if the two valves unhook at the same distance from either dead point the cut-off is equal; if otherwise, make adjustments and bring it so they will cut-off equal.

## AUTOMATIC GOVERNORS.

The governors on automatic engines are connected to the eccentric and fly (or balance) wheel, and so connected by means of levers, weights and springs, as to shorten the stroke of the eccentric and valve when engine has attained the proper speed at which it is set. The springs are set before leaving the work-



AUTOMATIC ENGINE.

shops, and should not be tampered with unless to change the engine to a slower or higher speed. When an engineer wishes to do this he must adjust each spring and weight equally to a hair, or the engine will pound and run uneven. Each builder of automatic engines supplies each engine with a book of instructions having therein descriptive cuts of valves, movements, etc.

## ELECTRICITY.

In this part of the book we will place in questions and answers the explanation of the dynamo, electricity, etc.

Q. What is the cause of a thunder storm or lightning?

A. The common conception of a thunder and lightning storm is that when clouds charged with the sun's potential energy, called electricity, approach and set up an inductive circuit to the earth, the earth forms the opposite condensing plate, and if the earth has the least resistance when the tension rises to a degree greater than the resistance can sustain, then the discharge will be from the clouds to the earth in a flash of fire, called lightning (or thunder bolt) the thunder is caused by the rush of the air together after being burnt out by the lightning.

Q. Give the different measurements used in electricity?

A. The "Volt," which is the unit of measure, known in dynamic terms as "Pressure." The "Ampere" is the measure of electricity or amount of current passed, or the amount transmitted or used. The "Ohm," called the resistance. The "Coulomb," called

foot pounds or a measure of current. The "Watt," called the 746th part of an electrical horse power.

Q. State as near as you know the force of a thunderbolt?

A. The pressure would be about 3,000,000 volts, and about 14,000,000 ampers used and power, about 2,000,000,000 watts, and the time for all about a twenty-thousandth part of a second.

Q. What is a magnet?

A. A magnet is anything that will attract and draw to it steel. Magnetism will produce electricity, and vice versa. This is the reason we can do so many wonders through the use of electricity.

Q. How would you make a magnet?

A. Take a steel horse shoe and wind it with fine copper wire, starting at one end of the shoe and wind around until we come to the other end of the shoe, and attach the two ends of wire to a battery, and the amperes of electricity will travel through the wire and charge the steel horse shoe with electricity, making of it what is called a magnet.

Q. Can you make a magnet out of a soft iron shoe?

A. No; not a permanent one, although the iron shoe makes a stronger magnet while the current of electricity passes through it, but as soon as the current ceases, the electricity leaves the shoe.

Q. How should a building be protected against lightning?

A. As a rule the conductor or lightning rod, as the electricians term it, is supposed to have a sort of power to attract the electric current or bolt to the ground, like a gutter pipe would carry water from the roof.

Q. Is a house safe with them on?

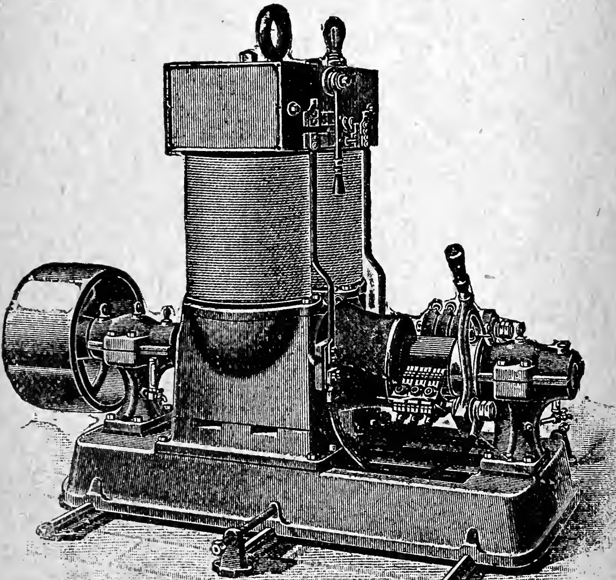
A. If enough of them are placed about the house top they may help, say one to every ten square feet.

Q. Is atmospheric electricity very dangerous or powerful?

A. It is about the same as the electricity we use for lighting purposes, and is detrimental to telephone, telegraph and other wires carrying low potential currents, also people of a nervous temperament.

Q. How should a lightning rod be at the the base to do any particular good, if any, and what is a practical thickness?

A. The wire or rod should be at least $\frac{1}{2}$ inch, and a solid rod having continuous metallic connections. The connection to the ground should be water, moist ground or gas or water pipes, the "bolt" rests and loses its force when it reaches the ground.



THE DYNAMO.

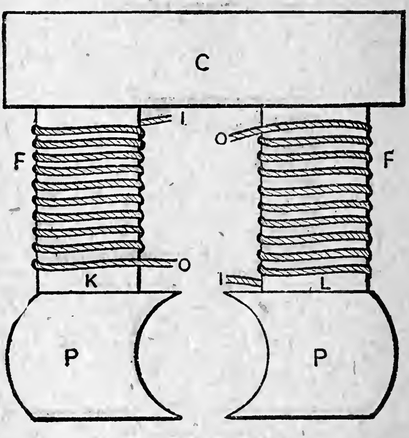
Q. Explain how you understand a dyamo and its use?

A. The dynamo is an electric machine which

is driven with a steam engine or water power, and is used to produce the electricity for electric lighting, electroplating, power, etc. This is where magnetism makes electricity.

Q. Explain the dynamo?

A. The dynamo is a combination of different parts so connected that when in working order it produces electricity, the combination consists




SKELETON DYNAMO.

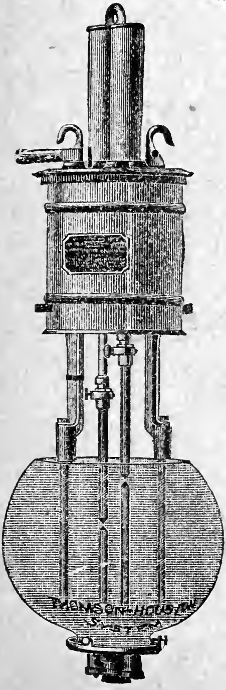
of twelve different parts, five of them constitute the magnet, namely: two "cores," K, L, two bottom cores or plate pieces, P, P, and one yoke C, The cores are hollow and wound with wires F, F, the amount is according to the use to which the dynamo is to be put. The poles are called the North and South poles; herewith will be found skeleton cut of magnet.

Q. State the amount of pressure or voltage there is in a dynamo for arc lighting?

A. There is about from 2,400 to 3,000 volts.

Q. State the amount of voltage on an incandescent dynamo?

A. It is about 110 volts, which is not considered dangerous and is sufficient for any number of sixteen candle power lamps.

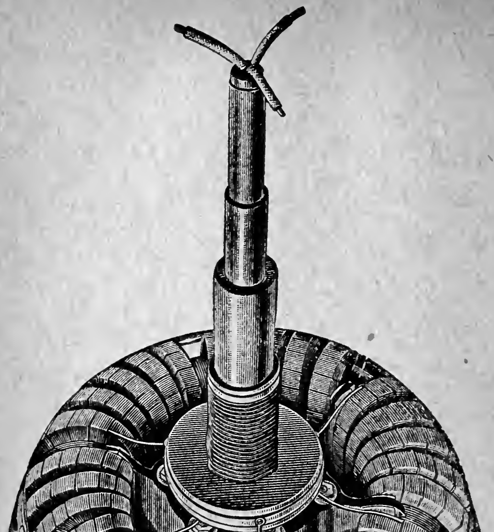



Q. Give a description of an arc light?

A. An arc light consists of a frame work, clock work, feeder on top, two carbon holders, and two carbons, wiring, etc.

Q. Why are two carbon pencils used?

A. If no resistance was given to the lamp or electrical current, we never would have a light. The current passing from one carbon to another breaks off a fine shower of carbon dust from the upper pencil as fine as flour and causes them to reach a white heat, the ends of carbons being hot, together with the shower of carbon dust at white heat makes the light.



ARMATURE.

Q. Give an illustration of this.

A. To illustrate this, take a rope tightly in your hand and let some one pull it quickly through and it would heat, viz: the resistance your hand gave the rope is what causes the heat, therefore the resistance the carbon sticks give the electrical current, causes the immense heat and does as stated in the answer before this one.

Q. For what purposes are arc lights used?

A. They are used for street lighting, also stores, etc.

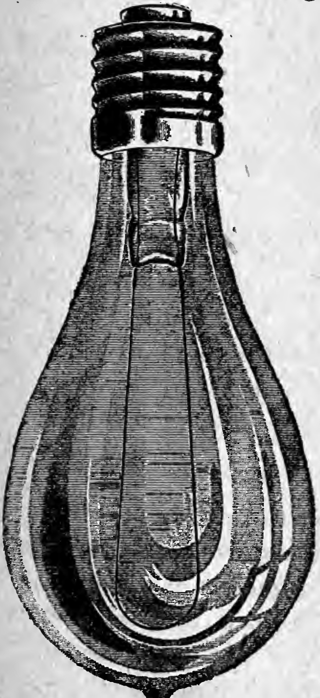
The armature rests in two journal box stands, on the armature is a commutator made of pieces of isinglass (or insolation) and copper; the copper is connected to the wires on the armature, and on each side of the armature rest two or more brushes two make the circuit complete.

Q. Are dynamos permanent magnets?

A. No, they are made of cast iron, except the copper and insulation, and as soon as the dynamo has stopped, the magnetism is a mere nothing; if the dynamo was made of steel it would retain the magnetism and the magnetism could not easily be regulated, where on the other hand the magnetism in the cast-iron dynamo can be easily regulated.

Q. Are there other electric lights besides the arc light just mentioned?

A. Yes; the incandescent lamp, which is shaped like a pear, it is made of thin clear glass, has a U shaped carbon in the glass which is made air tight containing a vacuum.



Q. Does the electrical current have to jump from one carbon to the other in an incandescent light the same way as in the arc light?

A. No; the incandescent carbon is a continual carbon and is about as large as a horse's hair, the carbon is made of carbonized bamboo cane it is joined inside by platinum and two thin copper wires, one being attached to a brass ring and the other to a brass button at the bottom of the lamp. These two are separated generally by plaster

of paris which is a nonconductor and no elec tricity will pass through it. The struggle between the electric current and the carbonized bamboo is so great and the carbon being the weaker of the two, has to submit to being heated to a white heat, which produces the light.

Q. State why it is that the carbon is not wasted as in the arc light?

A. Because the one, (arc light) is out in the atmosphere, while the other is heated in a vacuum.

Q. How long is the life of an arc light carbon, also an incandescent carbon.

A. The arc light (top) carbon will last about from ten to twelve hours and the lower one about twenty or thirty, the lower burns the slowest. In an incandescent globe it never wastes away as the vacuum (which means the exclusion of the oxygen air) prevents it. They (incandescent carbons) have lasted from one minute to 1500 hours, just as they are handled and used.

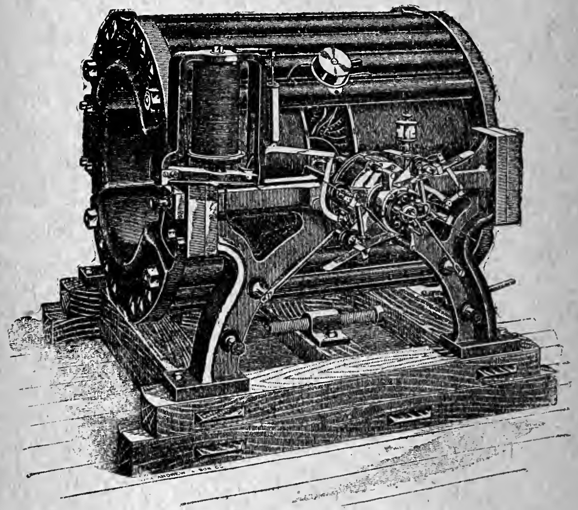
Q. What is a switch and its use?

A. There are many makes and kinds of switches, some for lamps, some for circuits, such as to cut out the lights in one room and leave another burn, or turn out ten lights or any number by switching off each separate light. A switch is a connection between two wires, which circuit can be broken at any time without doing

any particular harm to anything or anyone.

Q. Is there any danger of being shocked with an electric wire?

A. If the wire is insulated there is no danger of getting hurt, but there is if not covered, and you are standing on damp ground, as damp ground and water are great conductors of elec-



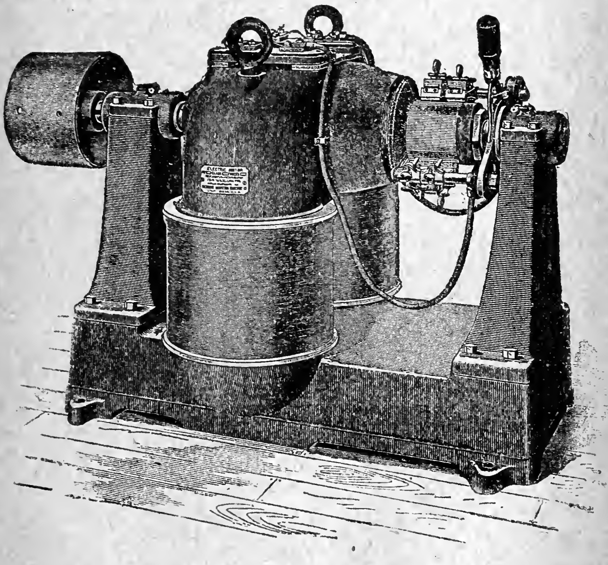
ARC DYNAMO.

tricity. If a man were to take hold of the bare wires used on street car lines and get hold with his feet clear of anything connected to the ground, the current would pass through him and not harm him but if his feet were to touch anything connected to the ground his life would pay the penalty,

## THE MOTOR.

Q. Of what use is the electric power?

A. It is one of the finest, cleanest and most convenient powers we can put to use for different purposes, such as driving different machines, sewing machines, printing presses, small factories, street cars, railway trains, etc.



ELECTRIC MOTOR.

Q. How is this kind of work done by electricity?

A. It is done through an electro-motor. (Motor)

Q. What is an electro-motor. (Motor.)

A. A motor is practically a dynamo machine

Q. Is the motor wound the same as a dynamo?

A. Yes; the dynamo is run by an engine and produces the electricity, while the motor gets its power from the dynamo.

Q. How does the dynamo deliver its electricity to the motor?

A. The dynamo delivers its electricity to the motor through two main wires, which are attached, one to each brush of the motor, thus making the driven dynamo a motor.

Q. Is the centre of the armature of the motor the same as the dynamo?

A. Not exactly, the principle is the same only the spool is made of iron plates fastened together, making one solid piece.

Q. What is meant by positive and negative?

A. It means North and South poles. The positive will not attract a positive, nor the negative attract a negative, a positive and a negative must always be together to do the work, on a motor armature there are crossed pieces of iron, two negatives and two positives, the magnet is positive and negative, one on each side of the crossed pieces of the armature, therefore the positive magnet draws the negative pieces on the armature

and the negative magnet draws the positive and so it keeps on. This is what turns the armature around, the more electricity that is transferred from the dynamo to the motor the faster the motor armature will revolve.

Q. What has that to do with moving the wheels of a car, or the moving of machinery?

A. For moving or running machinery, there is a pulley wheel on the end of the armature of the motor for a belt. For the car motor there is a strong toothed gear wheel which works compounded by more wheels moving or turning the axle and wheels of the car.

Q. How is the current of electricity conveyed from the overhead wire to the motor?

A. The electricity is conveyed by what is known as a trolley; attached to the trolley wheel is a wire leading down along side of a pole, through the inside frame of the car and to the motor brushes.

Q. How is the car stopped or started?

A. On each car is a motorman who attends to that part of the car, and the turning on and off of the current is done by a switch underneath the car, the switch is attached to a link chain, the chain is attached to an upright rod and pinion wheel at the end of the platform. The motorman when he wishes to start or

stop the car, turns a small crank handle which opens or closes a switch, whichever he wishes to do; of course, in stopping he uses the brake the same as on any other car.

## SPARKING OF COMMUTATOR.

Q. State the main causes of the commutator to spark?

A. Brushes not being properly or evenly set with the centre line on the commutator, bad insulation on the armature wiring, grease and dirt in the brushes coming in contact with the armature, also too much of the surface of brush covering the commutator.

Q. How would you find the trouble; state by the color of sparks?

A. If the brushes are too short the color is generally a greenish color, if the spark sputters or has a reddish color the brushes are too long, badly worn or have had too much contact; this causes the eating away of the commutator.

Q. If this is not prevented what will be the result?

A. If not attended to, the edges of the copper segments of the commutator will be eaten away and the commutator will become as rough as a piece of corduroy cloth.

Q. What will copper dust or oil do on a commutator?

A. It will carry the fire all the way around the commutator.

Q. Is this the only cause of such a spark?

A. No; sometimes it will be found near the spot that the insulation is charred or one of the connections between the armature wires and the copper segment of the commutator is loose or bad.

Q. What is the result or cause of this?

A. A short circuit.

Q. In what condition does the face of the commutator look near or in line of this spark?

A. It leaves a flat or hollow spot, such as could be made with the pene of a hammer.

Q. What should be done when a spot is found like the one mentioned?

A. Dress the commutator down to a round smooth surface.

Q. State a good way to keep a brush from wearing out too soon?

A. A good way is to turn the brush over.

Q. What causes a hot commutator?

A. Generally badly worn and dirty brushes

Q. With what can a dynamo be compared so as to be easily understood?

A. If an engineer wishes to understand the dynamo thoroughly he should compare it with the workings of a steam pump.

Q. Give an explanation of the pump theory?

A. The dynamo or pump gathers electricity and forces it through the wires, the same as a pump does water through a line of pipe, except that the dynamo forms a complete circuit from the dynamo out and returns to the dynamo whereas the pump forces in one direction or line, but if the pump forced the same water continually by having it flow back to the pump again its comparison would be with that of the dynamo.

Q. What else can be compared?

A. We can compare the steam pressure which overcomes the resistance or friction of the water in the pipe, with the voltage of the dynamo to overcome the resistance of the wire and carbons.

Q. With what would you compare amperes?

A. The amount delivered.

Q. With what would you compare the line-wire?

A. To the water pipe.

Q. With what would you compare the current?

A. Compare the current to the amount of water in motion,

Q. Suppose the dynamo was large and the wire small what would be the consequence or comparison?

A. The smaller the wire the more relative friction or resistance to the number of amperes delivered and the larger the main wires leading

from the dynamo the less relative friction or resistance in delivering the number of amperes, and current of electricity.

Q. What is meant by a converter on an alternating system?

A. It means in engineering a reducing value, or carrying a high voltage at the dynamo and passing through the converter the voltage is reduced for the lamps,

Q. What is an alternating dynamo?

A. It is a high voltage or arc machine using a converter (just explained) to which incandescent lights are attached.

Q. What is meant here by a continuous current of electricity?

A. It is understood that it is a current that flows in one direction, like steam in a pipe or water in a hose.

Q. What is meant here by an alternating current, also compare it to something?

A. Compare it to the crank and connecting rod; no dynamo or electric generator yet invented designed or made, ever did generate anything but alternating currents of electricity, or more correctly speaking waves or impulses of potential.

Q. How is the alternating current cummuted into a continuous current?

A, It is done by the commutator and brushes;

therefore the alternating is the original and only, and the continuous currents are obtained from any machine by manipulating the original or alternating current.

Q. What is the horse power of a continuous current dynamo the voltage being 110 and amperes 330?

A. The voltage being 110 and the amperes 330; we multiply $330 \times 110 = 36.300$ watts, and as 746 watts equal one horse-power, we divide $36.300 \div 746 = 48$ horse power. In continuous current engineering, the resistance of the wire is about all the obstruction that has to be calculated but in alternating circuits another factor comes in that of inertia, or self induction Independence depends directly upon the resistance of the conductors, and the inertia of the current in the circuit. If we construct a right angle triangle, and let the base equal the number of ohms resistance, then let the upright equal in a similar manner the inertia of self induction of the circuit; then the level line will be the independence or total resistance in the circuit. The inertia, or self induction of a circuit is just as great in one used for continuous currents as it is in one for alternating distribution, but as inertia only makes itself felt when a body is stopped or started, it is only with the continu-

ous current when that is first started and when it is stopped, that is, the electric current tends to hang back when being started, and to keep on moving when we wish to stop it, just as a fly-wheel does. The inertia of a continuous current shows itself when we open a switch through which a heavy current is passing. The inertia of the current prevents its stopping the instant the circuit is broken, and the fine arc often formed across the switch is the "coming along" of current left after the supply was cut off.

Electric inertia in any conductor depends largely upon the amount of magnets, motors, converters, etc., in the circuit, and it can be experimented with by pulling the fields of a motor or dynamo into a bell circuit. Ring the bell through the coils of wire thus added, and it will be noticed that the bell does not begin to ring as quickly as when the coils are not in circuit. Also that the bell rings a little after the contact has been broken, showing that the current lags behind. Another example, but more of magnetism than electricity, is in the position of the brushes on a dynamo; they have to be twisted around to fit the lag of the magnetic current.

We now come to the term "phase." If we take two alternating dynamos and couple the shafts together so that they are obliged to run

at the same speed, then we may say that the alternations of current have the same phase. The highest point or maximum of positive voltage occur at the same instant in both dynamos, hence the phases of the two machines are the same. Let the two machines be uncoupled and driver separated by belt and we may find that their positive maximums do not come exactly the same time, hence we may say the phase of the two dynamos are different. In other words, we may say that the maximum of positive electro-motive force occurs at exactly the same time in each machine; in any other case, the phases differ. An engineer can get a pretty good idea of the meaning of "phase" by standing in line with the crank shafts of two engines, both of which are running. If both cranks come to their highest points at exactly the same instant, their phase is the same, but if one of the cranks gradually draws ahead of the other then the phases are different.

We have now come to the terms often heard in connection with alternating currents, viz., one, two, three, four phase, etc. If we should take the two engines when they were running with their cranks at ninety degrees to each other, and suddenly couple them together thus, they would be running in two-phase, or bi-phase, like

the drivers of a locomotive. That may be called a "bi-phase" engine. If three engines were coupled together with cranks at 120, the combination would be called a "tri-phase" engine. An example of this may be found in the naptha launch engines, so well and favorably known. When four engines are coupled together they are called "quadruple," and the coupling of four dynamos follow the same nomenclature.

By coupling the engines we get rid of dead points, and raise the line of mean efficiency. The same thing is done in coupling up alternating dynamos, The mean efficiency line is raised, and the dead points are got rid of.

## TELEGRAPH AND BATTERIES.

**Q.** What is telegraphy?

**A.** Telegraph means to make known by sound.

Q. What constitutes a telegraphers outfit?

A. The battery, wire, sounder and key.

Q. How can one tell by sound the word meant?

A. By dots, dashes and spaces.

Q. Of what use is a battery?

A. To produce the necessary electricity.

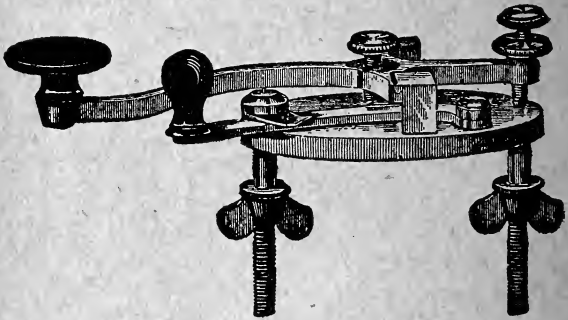
Q. Can any one telegraph without electricity?

A. Yes, within hearing distance, but for long distances one hundred feet to any distance in

miles electricity and iron wire must be used.

Q. State what is a telegraph key?

A. A telegraph key is usually made of brass, except the knob upon the handle, which is hard rubber or gutta percha. The second little knob is the switch to close when key is not in service and to let messages pass from one city or station to another on either side of your own, in other words it makes a free passage way for electricity.



TELEGRAPH KEY.

Q. When should this switch be open?

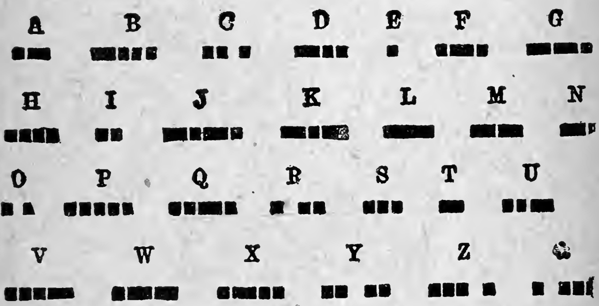
A. When one wishes to send a message.

Q. What is meant by a dot, dash and space?

A. To press the key down and let it spring back quickly, that means a dot. To press down the key and hold it there a little bit longer, that is a dash. To wait a little while before pressing down the key again, represents a space.

Q. Can you go through the alphabet?

A. Yes, A is a dot and dash : B is a dash and three dots : C is two dots, a space and one dot; D is a dash and two dots; E is a single dot; F is one dot, dash, one dot; G is two dashes and one dot; H is four dots ; I is two dots ; J is one dash, one dot, one dash, one dot; K, dash, dot, dash; L, long dash; M, two dashes; N, dash and dot ; O, dot, space, dot; P, five dots ; Q, two dots, dash, dot ; R, one dot, space, two dots ; S,



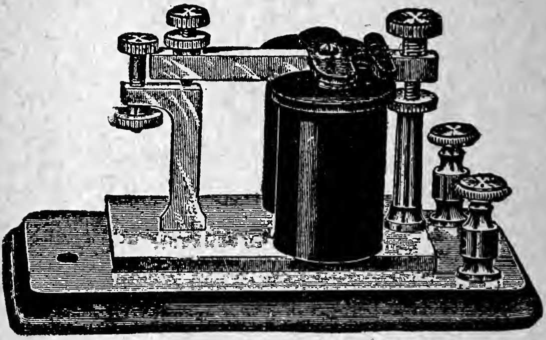

TELEGRAPHIC CODE.

three dots ; T, space ; U, two dots one dash ; V, three dots and dash ; W, one dot two dashes; X, one dot, one dash, two dots ; Y, two dots, space, two dots; Z, three dots, space, one dot; &, one dot, space, three dots. To make the above more plain we have placed the dots, dashes and spaces under each letter so they can be more plainly understood.

Q. What is a sounder?

A. A sounder consists of two black pillars which are iron cases wound with very fine copper wire, and is called an electro-magnet, and across the top of the two pillars is a piece of iron representing the armature, held up by a spring.

Q. How are the wire key sounder and battery connected with the single wire?



SOUNDER.

A. The battery is connected to the earth, the sounder to the battery, the key to the sounder, and the outside wire to the key.

Q. What is a battery?

A. There are various kinds of batteries, such as the Leclanch's porous cup battery, Law battery, Grenet battery, the Tillotson battery, and several other makes of batteries. Batteries are divided into two classes, "open circuit" and "closed circuit." The open eircuit batteries are used on telephones, electric bells, burglar alarms, gas lighting, annunciators, etc. The closed circuits are for electric lights and motors.